APPENDIX D: Flood Fighting Techniques on Levees

Appendix D Contents

Plates

1. Introduction

If a well-constructed levee of correct cross section is properly maintained and is not overtopped, it should hold throughout any major flood event. However, the levee is still in potential danger whenever there is water against it. The danger increases with the height of water, the duration of the flood stage, the intensity of the current, and the wave action against the levee face. There are three primary factors that lead to levee failures.

1. Overtopping
2. Seepage problems such as sandboils or slides
3. Erosion from the current or waves

Potential levee failures may be prevented if prompt action is taken and proper methods of treatment are employed. This appendix describes some of the general actions that should be taken to raise the crown of a levee or to respond to sandboils, seepage problems, or wave wash if these problems are identified during a patrol. The methods described have been developed from many years of experience in dealing with problems that arise as a result of high water, and should be followed as closely as possible. (The intent of this isn't to destroy personal initiative when dealing with unusual emergencies. On the contrary, if a dangerous situation occurs along a levee line, immediate action is demanded using the materials and labor at hand. However, an emergency is not a time in which to experiment, and these proven methods should be employed wherever possible.) Conditions and problems may arise which are not adequately covered by the suggestions provided or if there's any doubt as to the proper procedure that should be taken, the local U.S. Army Corps of Engineers district Emergency Management Office should immediately be consulted for advice and assistance.

2. Overtopping

A levee is overtopped when water flows over the levee crown. Low reaches in the levee crown must be identified as early as possible and raised to a uniform level. If the stream is predicted to approach or exceed the height of the existing levee, immediate attention should be given to raising the levee crown.

On the other hand, if the stream is likely to crest many feet beyond the elevation of the levee, the best approach may be to simply allow the levee to overtop, so that flood fight efforts can be redirected to other areas. If this is the case, low reaches in the levee crown need to be raised, leveled or otherwise prepared so that it overtops uniformly, to keep the damage to a minimum. Ideally, the levee should be allowed to overtop uniformly along the downstream portion of the system, so the protected area is "backfilled" with flood water. If the levee is breached due to the overtopping along the downstream portion of the FCW, it prevents the full force of the river's current from flowing into the protected area. An upstream breach will allow the river current to bring in much more debris (for example, entire trees), and would possibly cause much more scouring damage to the protected area than a downstream overtopping breach. It's very important that you contact the Corps district office when faced with decisions relating to the overtopping of a levee, as the Corps has a great deal of experience with flood fighting and can provide technical assistance and guidance as needed.

Generally, emergency barriers are constructed 2 feet above the current predicted river crest. For example, if the river is predicted to rise 1 1/2 feet beyond the elevation of the levee, then a 3 ½ foot capping would be necessary in order to maintain two feet of freeboard as a factor of safety. If the crest prediction increases during construction, additional height must be added.

2.1 Options for Raising a Levee

There are a number of ways that the levee crown can be raised. Provided the work is done well in advance of the high water, in areas where there is sufficient space for construction and with the proper equipment, the most efficient means of raising low stretches of the levee is to scarify the surface, haul in fill material and compact it in place, as discussed in section 2.2, below. However, this is not always possible. No heavy equipment should be used on a levee when water is near the top, as the vibration may cause a failure. In no case should such equipment be allowed on an earthen levee after the levee has commenced to seep. For these reasons, raising the elevation with compacted earthen fill may not be an option. The levee crown may alternately be raised with a sandbag capping or with flashboard structures. Jersey barriers have also successfully been converted into floodwalls during emergency situations.

Additionally, there are a large number of contemporary technologies that may be used to raise an emergency levee; including bladders, structurally supported membranes, and lightweight shells that are filled with sand from a bucket loader. The Corps' Engineer Research and Development Center has recently completed a rigorous and impartial study on several of these flood fight technologies. You are encouraged to visit http://chl.erdc.usace.army.mil/ffs for details on the tests and products, since this site will have the Corps' most current information on the subject, and the website will be updated as additional products are tested.

With so many options available for raising a flood barrier, there are several things you should consider as you decide how to best protect your community:

a. Cost of materials and labor

The materials for sandbag construction are generally much less expensive than the alternatives. Sandbag construction is very labor intensive, but at the same time, volunteer labor is often readily available during high water.

b. Available time

Flashboards or contemporary options are better suited to conditions when there is little time available for the construction, because they typically require less labor and can be put in place much faster than sandbag levees.

c. Allowable seepage

Most construction methods will allow some degree of seepage through the structure. As is the case with sandbags, modifications may be made to the basic designs so that the seepage is reduced, but these modifications usually take additional time to construct.

d. Suitability for construction in the given area

Sandbags are extremely versatile and sandbag structures can be constructed almost anywhere. Sandbags can be used to close small roads or to fill gaps, or can be built into long stretches of levees if there is adequate time and manpower. Flashboards and newer technologies are generally not as versatile, but depending on the technology and the construction, they are typically well suited for raising the elevation over longer stretches.

e. Equipment requirements

Sandbag structures can be built without heavy machinery, which may be required for some other options. There are a number of situations where it's not possible to use even light earthmoving machinery. For example, there might not be enough space for the machinery, or the foundations might be too unstable. Also, individual landowners may object to the use of machinery over their properties.

f. Necessary elevation

Though sandbag levees are best suited for elevations of 3 feet or less, they have successfully been used to raise elevations by 20 feet or more in extreme flooding situations. Flashboards are typically only built to a maximum of 3 feet, and the elevation provided by other technologies varies. In deciding between the various options, it's important to consider how reliably they can forecast the crest height of the river. If the river stage might rise several feet beyond what is currently predicted, a sandbag levee could be raised higher, while it would be much more difficult to raise something like a flashboard or Jersey barrier structure.

g. Disposal

Burlap sandbags are biodegradable and relatively easy to remove and dispose of. Other options typically take much longer to remove and create more waste. Some are reusable.

Situations may arise when one of the more contemporary products may be readily available and appropriate for the given conditions, when there would be insufficient workers available to protect the area with sandbags or when time was extremely limited; and in these situations the cost of using these products may be justified. While it would be prohibitively expensive for the Corps to stockpile enough inventories to adequately address all problems that might be faced across the country, the Corps may purchase such items and make them available for public sponsors if conditions warrant. However, in the majority of situations, sandbags are almost always preferred and recommended during flood fights when construction with earthen fill is not possible. The following sections provide specific guidance on raising levees using earthen fill, sandbags, and flashboards.

2.2 Raising a Levee with Earthen Fill

a. Borrow Area and Haul Road

Borrow material can become a critical item of supply in some areas due to long haul, project isolation, or for other reasons. The two prime requisites for a borrow area are that adequate material be available and that the site be accessible at all times. The quantity estimate plus an additional 50 percent should provide the basis for the area requirement, in order to provide suitable materials for levee construction as covered below. The area must be located so that it will not become isolated from the project by high water. Local contractors and local officials are the best source of information on available borrow areas. In undeveloped areas, the area should be cleared of brush, trees, and debris, with topsoil and humus being stripped. In early spring, it will probably be necessary to rip the area to remove frozen material. An effort should be made to borrow from the area in such a manner that the area will be relatively smooth and free draining when the operation is complete. The haul road may be an existing road or street, or it may have to be constructed. To mitigate damages, it is highly desirable to use unpaved trails and roads, or to construct a road if the haul distance is short. In any case, the road should be maintained to avoid unnecessary traffic delays. The use of flagmen and warning signs is mandatory at major crossings, such as highways, near schools, and at major pedestrian crossings. It may become necessary to stockpile material near anticipated trouble areas.

b. Equipment

One of the important considerations in earthwork construction is the selection of proper equipment to do the work. Under emergency conditions, obtaining normally specified earthwork equipment will be difficult and the work will generally be done with locally available equipment. It may be wise to call for technical assistance in the early contract stage to ensure that proper and efficient equipment use is proposed. If possible, compaction equipment should be used in flood barrier construction. This may involve sheepsfoot, rubber-tired, or vibratory rollers. Scrapers should be used for hauling when possible because of speed (on short haul) and large capacity. Truck haul, however, has been the most widely used. A ripper is almost essential for opening borrow areas in the early spring. A bulldozer of some size is mandatory on the job to help spread dumped fill and provide some compaction.

c. Foundation preparation

One of the primary differences in the construction of emergency levees and the construction of permanent levees lies in the preparation of the foundation. Prior to any embankment construction, it's very important that the foundation is prepared, particularly if the levee is to be left in place. For emergency construction during spring flooding, the first item of work will probably be snow removal. The snow should be pushed riverward so as to decrease ponding when it melts. Any trees that might be present should be cut and the stumps removed. If at all possible, any obstructions above the ground (brush or similar debris) should be removed. The foundation should then be stripped of topsoil and surface humus. (Clearing and grubbing, structure removal and stripping should be performed only if time permits.) Stripping may be impossible if the ground is frozen, and in this case, the foundation should be ripped or scarified, if possible, to provide a tough surface for the material to bond to. Every effort should be made to remove all ice or soil containing ice lenses. Frost or frozen ground can give a false sense of security in the early stages of a flood fight. It can act as a rigid boundary and support the levee, but when it thaws, the soil strength may be reduced sufficiently for cracking or the development of slides. The ice also forms an impervious barrier to prevent seepage. This may result in a considerable build-up in pressure under the soils landward of the levee and, upon thawing, pressure may be sufficient to cause sudden blowouts. If this condition exists, it must be monitored, and one must be prepared to act quickly if sliding or boiling starts. If stripping is possible, the material should be pushed landward and riverward of the toe of levee and windrowed. After the flood, this material can be spread on the slopes to provide topsoil for vegetation.

d. Materials

Earth fill materials for emergency levees will come from local borrow areas. An attempt should be made to utilize materials which are compatible with the foundation materials as explained below. However, due to time limitation, any local materials may be used if reasonable construction procedures are followed. The materials should not contain large frozen pieces of earth.

i. Clay

Clay is preferred because the section can be made smaller (steeper side slopes). Also, clay is relatively impervious, and has relatively high resistance to erosion when it's compacted. A disadvantage in using clay is that adequate compaction is difficult to obtain without proper equipment. Additionally, the water content in impervious fill can impact the compaction needs. Efforts are typically made at the borrow site to obtain material with the optimal moisture; otherwise, if that is not possible, more time may be required for compaction. Another disadvantage is that the clay may be wet and sub-freezing temperatures may cause the material to freeze in the borrow pit and in the hauling equipment. Weather could cause delays and should definitely be considered in the overall construction effort.

ii. Sand

If sand is used, the section should comply as closely as possible with recommendations in the paragraph titled Levee Section, below. Flat slopes are important, as steep slopes without poly coverage will cause seepage through the levee to outcrop high on the landward slope, and may cause the slope to slump.

iii. Silt

Material that is primarily silt should be avoided, and if it is used, poly facing must be applied to the river slope. Silt, upon wetting, tends to collapse under its own weight and is very susceptible to erosion.

e. Levee Section

In standard levees, the foundation soils and available construction materials generally dictate the design configuration of the levee. Therefore, even under emergency conditions, an attempt should be made to make the embankment compatible with the foundation. Information on foundation soils may be available from local officials or engineers, and it should be utilized. The three foundation conditions and the levee sections cited below are classical and idealized, and usual field conditions depart from them to various degrees. However, they should be used as a guide so that possible serious flood fight problems might be lessened during high water. In determining the top width of any type of section, consideration should be given as to whether a revised forecast will require additional fill to be placed. A top width adequate for construction equipment will facilitate raising the levee. Finally, actual levee construction will in cases, depend on time, materials, and right-of-way available.

i. Sand Foundation

If the foundation material under the emergency levee is sand or some other pervious material, the following guidance is provided:

- If the levee section is to be made of sand, use a minimum of 1V (Vertical) on 3H (Horizontal) river slopes. A 1V on 4H river slope is preferable, and will be less susceptible to erosion, but a 1V on 3H slope is considered an adequate minimum for emergency purposes. Use 1V on 5H for the landward slope, and 10-foot top width.

- If the levee section is to be made of clay, use 1V on 2 1/2 H for both slopes. 1V on 3H slopes are preferable, but 1V on 1 ½ H is an acceptable minimum for emergency purposes. The bottom width should comply with creep ratio criteria; i.e., L (across bottom) should be equal to C x H; where C=9 for fine gravel and 15 for fine sand in the foundation, and H is levee height.

This criteria can be met by using berms either landward or riverward of the levee. Berm thickness should be 3 feet or greater. Berms are used mainly to control or to relieve uplift pressures and will not reduce seepage significantly.

ii. Clay Foundation

If the foundation material under the emergency levee is clay, the following guidance is provided:

- If the levee section is to be made of sand, it should be constructed with 1V on 3H for the river slope. Again, a 1V on 4H is preferable, but the steeper slope is considered adequate for emergency purposes. Use 1V on 5H for the landward slope, and a 10-foot top width, as described in the previous section.

- If the levee section is to be made of clay, use 1V on 2 1/2 H for both slopes. 1V on 3H slopes are preferable for clay levees, but 1V on 1 ½ H is an acceptable minimum for emergency purposes. With a clay foundation, there is no need to construct additional berms.

iii. Clay Layer over a Sand Foundation

If the foundation material is such that there is an impervious clay layer resting over a pervious sand layer, the following guidance is provided:

- If the levee section is to be made of sand, use a minimum of 1V (Vertical) on 3H (Horizontal) river slopes for emergency purposes. A 1V on 4H slope is preferable, if this construction is possible. 1V on 5H landward slope, and 10-foot top width. In addition, a landside berm of sufficient thickness may be necessary to prevent rupture of the clay layer. The berm may be constructed of sand, gravel, or clay, but since berms made of clay generally need to be wider and thicker than those made of pervious materials, it would probably reduce the construction effort to build the berm with sand or gravel, if these materials were available. Standard design of berms requires considerable information and detailed analysis of soil conditions. However, prior technical assistance may reduce berm construction requirements in any emergency situation.

- If the levee section is to be made of clay, use 1 V on 2 1/2 H for both slopes. Again, 1V on 3H slopes are preferable, but 1V on 1 ½ H is an acceptable minimum for emergency purposes. Additionally, a berm may be necessary to prevent rupture of the impervious top stratum.

f. Placement

Layers should be started out to the full width of the embankment base, and subsequent lifts shall be placed so that the tops are substantially horizontal. In general, the levee section should be homogeneous. However, when materials of varying permeability are encountered in the borrow area, the more pervious material should be placed on the landside of the embankment.

g. Compaction

As stated above, obtaining proper compaction equipment for a given soil type will be difficult. It is expected in most cases that the only compaction will be from that due to the hauling and spreading equipment, i.e., construction traffic routed over the fill. It is to be realized that even the minimum requirements may not be possible or feasible, and, if situation demands, material should be placed and compacted in any way possible and the levee observed closely for signs of distress. A construction engineer should ideally oversee the design of emergency levees. Use of these guidelines should not be taken as a guarantee that a safe structure will be constructed.

i. Pervious Fill

Material shall be placed in layers not more than 12 inches in thickness prior to compaction. In emergency situations, each layer should be compacted at the very minimum by one pass of the hauling equipment. However, whenever time, cost and availability of equipment will permit, a much safer structure will result if each layer gets compacted by a minimum of 3 complete passes of a crawler-type tractor, or by 2 passes of a vibratory roller.

ii. Impervious Fill

Fill material shall be placed in layers not exceeding 9 inches prior to compaction. In emergency situations, each layer should receive at least one complete coverage of the track or wheel of the placing equipment or equivalent. However, whenever time, cost and availability of equipment will permit, a much safer structure will result if each layer gets compacted by a minimum of 4-6 complete passes of a tamping type roller or 4 complete passes of a rubber-tired roller.

2.3 Raising a Levee with Sandbags

a. Sandbags

Sandbags are available in plastic and in burlap. The preferred bags are untreated, close weave burlap sacks available at feed or hardware stores. Empty bags should be stockpiled for emergency use, and can be stored for approximately 8 years in a rodent-free environment with low humidity. Don’t fill the bags ahead of time, because they will deteriorate quickly. Commercial polypropylene sandbags are also effective in a flood fight, but since plastic bags are not readily biodegradable, burlap bags will allow more options for disposal if the bags are not going to be reused. (No sandbags should be left in place after the flood fight, regardless of whether they are burlap or plastic.) Do not use garbage bags, as they are too slick to stack; and don’t use feed sacks, as they are too large to handle. Experience shows that bags work well if they are approximately 14 inches wide and 24 inches deep.

b. Fill Material

A sandy soil is most desirable for filling sandbags, as it's easiest to shovel, and the bags can most easily be shaped as needed. Fine sand tends to leak through the weave in the bag, and if it is used it should be double bagged. Silty soils also tend to leak through the bags, and both silty soils and clays are difficult to shape into place. Gravelly or rocky soils are generally poor choices for sandbag structures because of their permeability, though rocks and gravel may be used in sandbags in order to divert water flows, to fill holes, or to hold objects in position. However, any usable material at or near the site has definite advantages. Material should generally not be removed from within 500 feet of the landward toe of a levee, except for in extreme emergency situations.

c. Sandbag Filling

Filling sandbags manually requires two people. One member of the team folds the throat of the bag outward to form a collar, and holds it open so that the other person can shovel in material. The one holding the bag should hold it between or slightly in front of his or her feet, either crouching with his elbows resting on his knees or standing with his knees slightly flexed, while keeping his head and face as far away from the shovel as possible. Both people should be wearing gloves to protect their hands, and safety goggles may also be desirable, especially on dry or windy days.

Figure D.1 *This two-person team is positioned properly for sandbag filling.*

If they are available during large-scale operations, bag-holding racks and power loading equipment can expedite the operation. Sandbag filling machines can be very effective if they are functioning correctly. Alternately, some people have reported success with improvised sandbag filling devices during a flood response. Inverted traffic cones or large metal funnels have been placed into holes in a table, and feeding bins with doors in their bases have been used to pour sand into bags.

Regardless of what method you use to fill them, bags should be filled between one-half (1/2) to two-thirds (2/3) of their capacity. This keeps the bag from getting too heavy, but more importantly, sandbag structures do not seal or keep out water as well if the bags are more than 2/3 full. Be very careful not to overfill or under fill the bags.

d. Tied vs. Untied Bags

Although tied sandbags are generally easier to handle and stockpile, untied sandbags are recommended for most situations, because untied bags make a better seal when they're stacked. Since the bags aren't more than 2/3 full, they can be transported almost as easily whether they're tied or untied. Tied sandbags should be used only for special situations when the bags need to be pre-filled and stockpiled, or for specific purposes such as filling holes or for holding objects in position.

e. Preparing the Ground

Any debris must be removed from the area before the bags are laid in place. Typically, flat headed shovels are used to scrape up ("scarp") the sod or gravel where they are to be laid, to get down to the solid ground where the bags are to be laid. Do not scarp the ground beyond the area directly under the sandbags, because the sod cover in other areas is needed to protect the ground from erosion.

Before laying the bags along the entire length of an area to raise the levee, it's important that you first fill in any low areas with sandbags or with tightly packed earth, so that subsequent sandbag layers will be kept level.

f. Sandbag Placement

When laying the sandbags, the open end of the unfilled portion of the bag is folded over to form a triangle. If tied bags are used, flatten or flare the tied end. Place the partially filled bags lengthwise and parallel to the direction of flow, so the bottom of the bag faces downstream and the folded end faces upstream. (This positioning reduces the chance that floating debris will snag on the tucks and open the bags.)

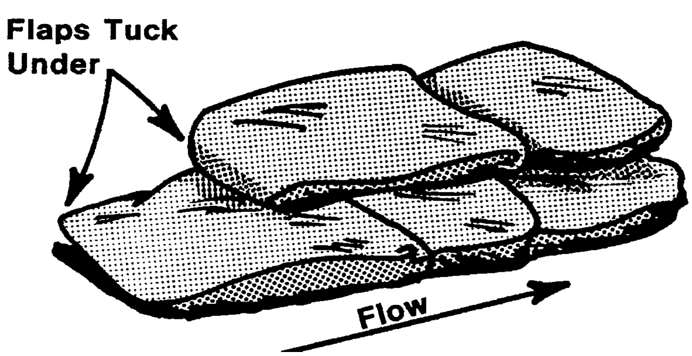


Figure D.2 *Sandbag placement – tucking in the flaps.*

Figure D.3 *Sandbag placement – compacting bags together.*

Tuck the flaps under, keeping the unfilled portion under the weight of the sack. Overlap the next bag slightly over the one before it, so that the top of that sandbag layer can be flattened without leaving any gaps between the bags. Once a bag is placed, it's very important that you then walk over it, stomp on it, or maul it into place to eliminate voids and form a tight seal.

When succeeding layers are added, stagger the bags like bricks, so that each one is placed over the gap between the two below it. This ensures that each seam is interlocked between bags and strengthens the structure. (There should never be less than 1/3 the length of a bag overlapping with the ones beneath it.) When placed properly, each bag should raise the elevation of the structure by 4 inches.

g. Sandbag Levees

Sandbags can be used to raise the height of an existing levee or can be used over open ground to protect an area with no levee at all. Any time a sandbag levee will be constructed over one layer high; the bag should be stacked in a pyramid structure to ensure stability. The basic rules of thumb in constructing these structures is that they must be approximately <u>three times as wide as they are high</u>, and the sandbags should be staggered within each layers just as they are staggered from one layer to the next. The directions of the bags (transverse or longitudinal) may be alternated, as long as no loose ends are left exposed. Use this rule of thumb in determining the dimensions of the pyramid:

- 1 bag in length equals about 1 foot
- 3 bags in width equals about 2 ½ feet
- 3 bags in height equals about 1 foot

When building these structures on top of an existing levee, the bags should begin 1 foot from the riverward crown (shoulder) of the levee. Where space is extremely limited on the levee crown, this distance may be reduced but the structure should never be built less than 6 inches from the edge of the levee crown. Stamp each bag in place, overlap sacks, maintain staggered joint placement, and tuck in any loose ends.

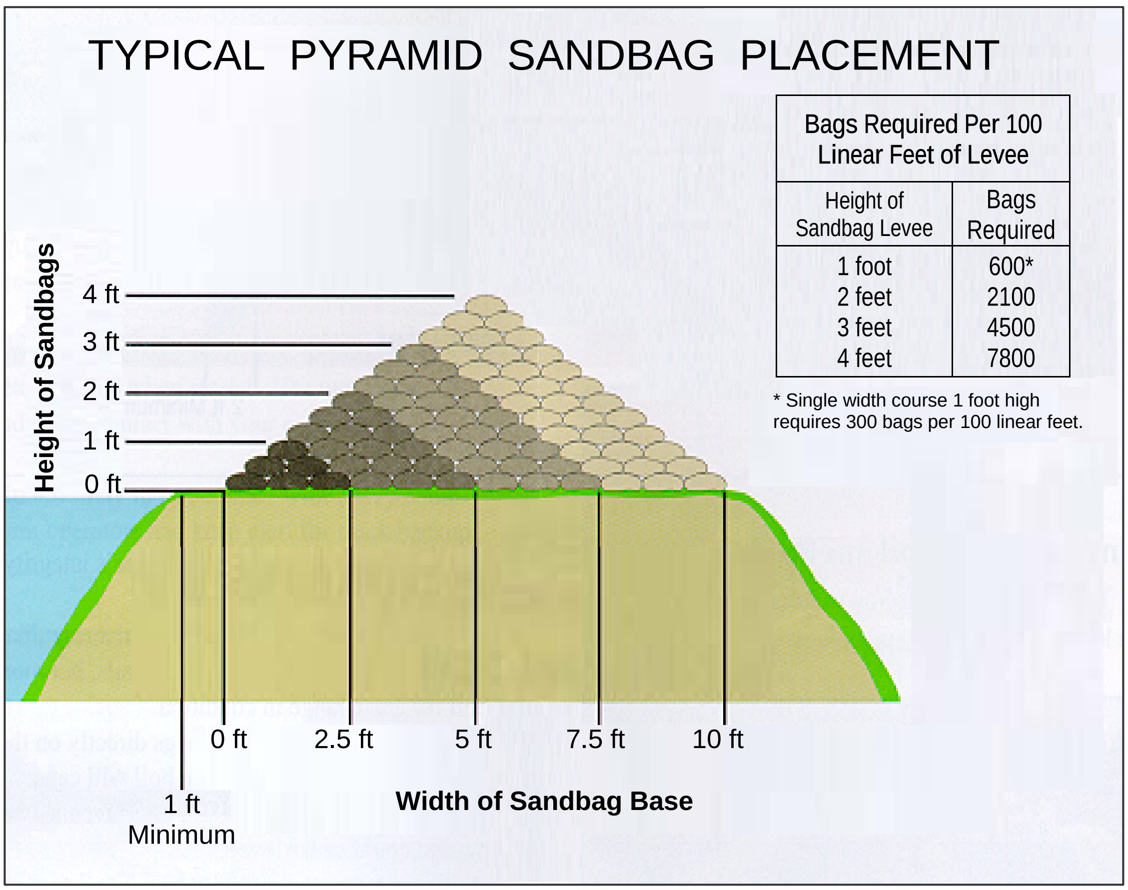


Figure D.4 *Pyramid sandbag placement.*

h. Material, Tools, and Labor Requirements for Sandbag Levee

Listed below are the materials, tools, and labor required to construct 100 linear feet of sandbag levee, two feet high, with a haul distance of 1 mile round trip.

i. Materials and Tools

1,800 Sandbags
10 Shovels
27 Flash lights
10 Tons sand (approx)
2 Emergency light sets
2 Radios or cell phones (one at filling site; one at laying site)
6 Pickup trucks

ii. Labor Requirements:

10 Filling sandbags
5 Loading
6 Hauling
5 Laying
2 Foremen (1 at sandbag filling site, 1 at work site)
28 People required, total

iii. Time Requirements:

With given resources, the time for completion is estimated at 2 ½ hours, from start to finish.

i. Bonding Trench and Plastic Sheeting

Seepage through a sandbag structure can be kept to a minimum if the structure is built carefully using untied bags. One method that's been successfully used to reduce the seepage through a sandbag levee and to increase the horizontal stability is to construct a bonding trench under the structure before the sandbags are laid in place, as pictured below. An additional precaution is to build the structure over some plastic sheeting, which is pulled up and over the structure once it's complete.

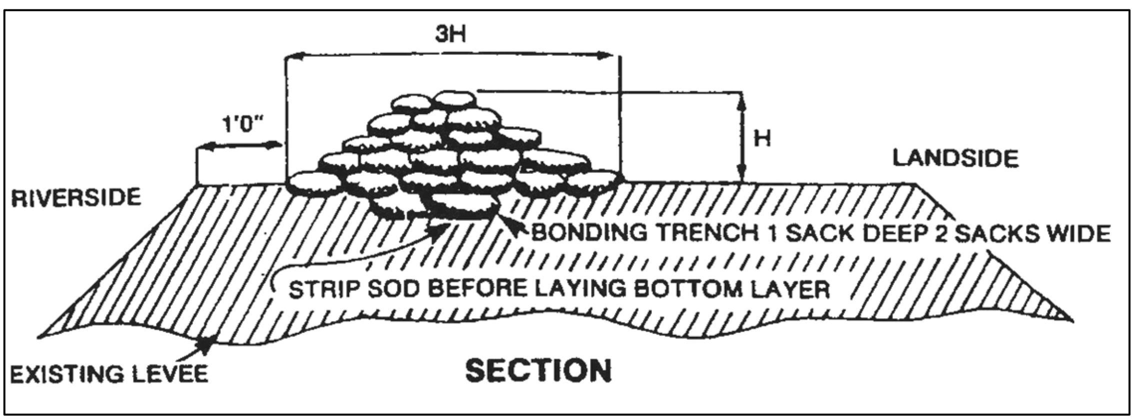


Figure D.5 *Sketch of a typical levee raise with bonding trench.*

While it's always recommended at least to scarp the ground before the bags are laid, the decision to dig this trench or use the plastic sheeting depends on local conditions, as well as on the expected height of the structure and the time that's available to build it. One of the primary concerns when considering bonding trenches and/or plastic sheeting is the amount of time that's available. If there's sufficient time and adequate material, the seepage can be reduced, but if there is very little time available, the ground should be scarped and a typical sandbag structure constructed with no bonding trench at all. An additional concern is whether the sandbag levee would have to be raised in the future, because any plastic sheeting has to be removed before the structure can be raised.

If plastic sheeting is to be used in conjunction with the sandbag levee, begin by digging a bonding trench 2 sandbags wide and one sandbag deep. The edge of the plastic is placed in the hole and weighed down with sandbags, with most of the plastic laying out in the direction of the river. It's very important that the plastic is <u>never</u> laid across the entire width of the sandbag levee base. Sandbag levees are held together by frictional forces between the bags and with the ground surface; sandbag structures are much less stable when wrapped with plastic, and can slide apart under high water. Construct the sandbag levee over the sheeting, pull the plastic up and overtop of the structure and weigh it down with sandbags on the landward side. Always work from downstream to upstream so that the upstream plastic seams all overlap the ones downstream, in order to prevent debris from snagging the plastic and pulling the sandbag levee apart.

2.4 Raising the levee with Flashboards or Lumber and Sack Cappings

If it appears that the levee raise would have to hold back more than 18 inches of water, consideration should be given to use of a lumber and sack capping or a flashboard capping. A lumber and sack capping is shown in plate 3, which may be used as a guide to estimate the materials required for a levee raise of about 3 feet. A flashboard structure is very similar, but the face of the structure is constructed of plywood instead of boards. These wooden facings provide a more positive control against excessive through seepage than is provided by sandbags alone. Either structure can be supported from behind with either sandbags or with compacted earthen fill, depending on how accessible the crown of the levee is to earthmoving machinery.

Additionally, plastic sheeting may be installed on the riverside face of the plywood or flashboards, to protect the wood and reduce seepage through the flashboards. Flashboards do tend to leak a little, depending on how they are constructed and how the boards expand when they're wet; though these structures are never constructed without a sandbag backing. If plastic sheeting is to be used, it should extend 1' riverward from the riverside bottom of the plywood/flashboard. A row of sandbags should then be stamped into place along the riverside bottom edge of the plywood/flashboards to help prevent seepage under the flashboard system. The plastic is brought up the riverside of the plywood/flashboards and over the top to the landside supports and held in place by sandbags or nails where necessary. Field conditions, the available time, and the availability of materials would dictate the actual requirements.

3. Seepage

As a river or stream rises, the hydrostatic pressure against a levee slope increases significantly and can force water into and under the levee embankment. Even when a levee is properly constructed and of such mass to resist the destructive action of flood water, this seepage tends to push its way through regions of least resistance (such as sandy layers under the levee or animal burrows) out to the surface on the landward side of the structure. If there isn't sufficient pressure on the landward side to hold back the seepage water, it will break through the ground surface on the landward side, in the form of bubbling springs, which erode and carry soil particles from under the levee.

Seepage is almost impossible to eliminate and attempt to do so may create a much more severe condition. Seepage is generally not a problem unless 1) the landward levee slope becomes saturated over a large area, 2) seepage water is carrying material from the levee, or 3) pumping capacity is exceeded. Pumping of seepage should be held to a minimum, and ponding should be allowed during high water to the extent that it doesn't cause damages. Several levees were endangered during past floods by attempts to keep low areas pumped dry, and additional time and effort were expended in controlling sandboils caused by pumping. Therefore, seepage should be permitted if no apparent ill-effects are observed and if adequate pumping capacity is available.

3.1 Effects of Underseepage

Underseepage can produce three distinctly different effects on a levee, depending upon the condition of flow under the levee.

a. Piping Flow

In extreme conditions of excessive underseepage, the movement of seepage water erodes the foundation materials, and a clearly defined pipe or tube develops under the levee. Unless corrective actions are taken, water continues to erode and enlarge this pipe, so that a cavern develops under the levee, and levee material collapses to fill in the void. In an advanced state, piping under the levee can be identified by a slumping of the levee crown, and the levee can quickly fail if it's overtopped through this low spot. To prevent this condition from developing, any boils found to be transporting soil material need to be treated as early as possible.

b. Non-Piping Flow

In this case, seepage water flows under the levee without following a well-defined path, and results in one or more boils outcropping at or near the landside toe. The flow from these boils tends to undercut and ravel the landside toe, resulting in sloughing of the landward slope. Sloughing is the movement of small amounts of soils from the embankment slopes. Sloughing may also occur if the levee embankment becomes saturated as a result of prolonged high creek stages. Evidence of this type of failure is found in undercutting and raveling at the landside toe.

c. Saturating Flow

In this case, numerous small boils, many of which are scarcely noticeable, outcrop at or near the landside toe. While no boil may appear dangerous in itself, a group of boils may cause significant damage. The flowing water may erode away supporting material and/or keep the area saturated and cause flotation ("quickness") of the soil, reducing the shearing strength of the material at the toe (where maximum shearing stress occurs) which could lead to slope failure. In a slope failure condition, a substantial section of the levee embankment breaks away along a clearly defined crack and slides away from the levee. The displacement of the soil will result in a reduction in the cross sectional area of the levee and poses a major threat to the integrity of the structure.

3.2 Sandboils

a. Identification of Sand Boils

Sandboils usually occur within 10 to 300 feet from the landside toe of the levee and, in some instances, have occurred up to 1,000 feet away. Boils will have an obvious exit (such as a rodent hole), but the hole may be very small. When material is carried upward through a boil, it is deposited in a circular pattern around the exit location, and is comparable to an ant hill or volcano. Alternately, sandboils may exit into standing water. In this case, they may be difficult to identify, especially if the hole is small and the water cloudy from siltation. If you see any movement in what appears to be standing water on the landward side of the structure, this may be the exit point for a sandboil. Carefully approach the site, disturbing the water as little as possible, and let the water settle in order to look for the exit point. If there is no distinct hole, the water flow is not a threat. All boils should be conspicuously marked with flagging so that patrols can locate them without difficulty and observe changes in their condition.

You can tell how serious a boil is by the color of the water that is coming out. If the water is relatively clear, it means that there is relatively little material being eroded away through the boil. The site should be monitored regularly for changes, but nothing else should be done to treat the clear boil. If it’s dark or muddy, then it’s full of material that’s been eroded away from under the levee, and must be treated immediately. Boils may quickly grow very large, and boils, which are discharging clear water, may suddenly begin to discharge soil materials along with the seepage flows. For this reason, any boil, whether the flow is clear or muddy, can potentially lead to the failure of the levee and must be monitored closely.

b. Treatment of Sandboils

The most common and accepted method of treating sandboils that are displacing soil is to construct a ring of sandbags around the boil(s) as illustrated in Figure D.7. The purpose of the ring is to raise a head of water over the boil to counterbalance the upward pressure of the seepage flow. The height of the water column is adjusted so that the water exiting the boil runs clear and no longer removes soil from the levee foundation. It’s extremely important that the flow of water is never stopped completely, as this may cause additional boils to break out nearby. Treated areas should be kept under constant surveillance until the water recedes.

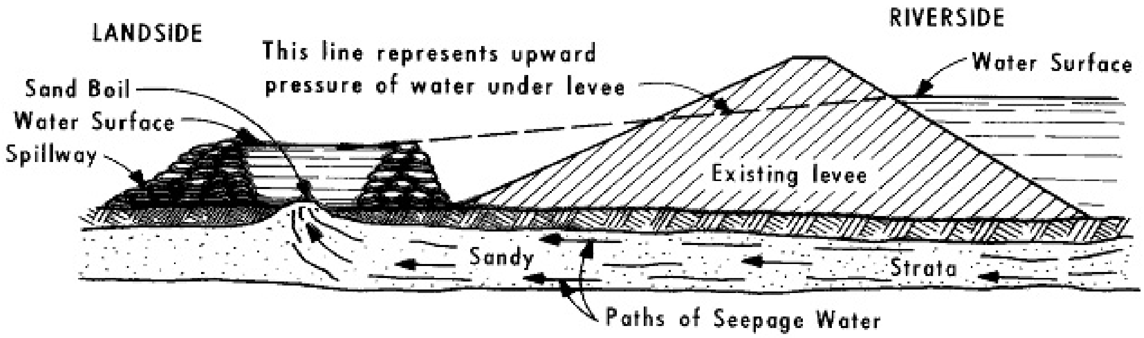


Figure D.6 *To treat the sandboil, the pressure of the seepage water is counterbalanced by hydrostatic pressure from the column of water in the ring levee.*

The diameter and height of the ring will depend on the actual conditions at each sandboil. The base width should be at least 1½ times the contemplated height, and the inner ring of sandbags should begin between one and three feet from outer edge of the sandboil. "Weak" or "quick" ground near a boil should be included within the sack ring to prevent these areas from developing into new boils when the active boil is treated. Where several sandboils develop in a localized area, a ring levee of sandbags should be constructed around the entire area. The ring should ideally be of sufficient diameter to permit sacking operations to keep ahead of the flow of water. When a sandboil is located near the levee toe, the sandbag ring may be tied into the landside slope of the levee, as shown in Figure D.8.

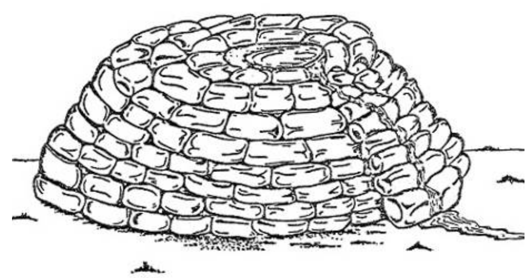


Figure D.7 *Sketch of a typical ring levee with spillway.*

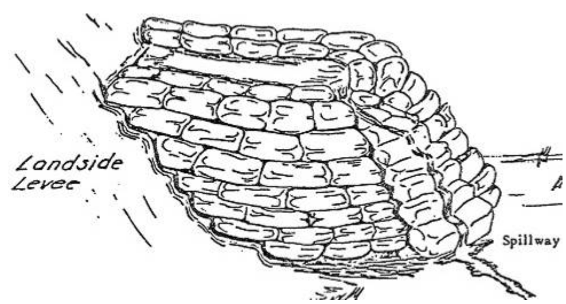


Figure D.8 *Sketch of ring levee tied to a levee slope, with spillway. Construction against the levee slope results in a U-shaped sandbag "chimney."*

The base or foundation for the sack ring should be cleared of debris and scarified to provide a reasonably watertight bond between the ground surface and the sandbags. The ring is constructed with sacks filled approximately two-thirds (2/3) full of sand, and tamped firmly into place. Do not tie the ends of the sacks. When adding subsequent layers, the joints should be staggered for stability and water tightness. The untied ends of sandbags should be laid towards the inside of the ring and folded under. The height of the sack ring should be only sufficient to slow the flow until the water exiting the boil runs clean. Never place sandbags directly over the sandboil or attempt to completely stop the flow through the boils, as this may result in other boils developing nearby.

A spillway or exit channel should be constructed on the top of the sack ring so that the level of the water in the ring levee can be adjusted, and the overflow water can be carried a safe distance from the boil, away from the direction of the levee. Because the height of the water is the critical factor in adjusting the rate of flow through the boil, the spillway will require constant monitoring and adjustment once the sandbag ring levee is filled with water. This spillway is normally constructed of sandbags, but alternately, a V-shaped drain can be constructed of two boards; or PVC pipe, plastic sheeting, or other materials may be helpful in building the spillway.

c. Material, Tools, and Labor Requirements for Sandbag Ring Levee:
Materials, tools, and labor required to construct a Sandbag Ring Levee 2½ feet high and 10 feet in diameter with a haul distance of 1 mile round trip.

i. Materials and Tools:

1,125 Sandbags
5 Shovels, long or short handle
9 Tons of sand (approximately)
5 Pick up trucks
2 Radios or cell phones (one at filling site; one at laying site)
2 Emergency light sets
15 Flashlights
15 Pairs of work gloves

ii. Labor Requirements:

4 Filling sandbags
3 Loading/ carrying
5 Hauling to work site
3 Laying (placement)
2 Foremen (1 at sandbag filling site 1 at work site)
17 People required, total

iii. Time Requirements:

With given resources, time for construction is estimated to be 1-½ hours from start to finish.

d. Alternate Methods of Treating Sandboils

An alternate method of ringing sandboils is by use of corrugated sheet-steel piling, as shown in Figure D.9. The area is cleared of debris, and the piling is driven about 1-½ feet into the ground around the boil. This method accomplishes the same task faster than sandbagging, but is limited in use by the availability of material, equipment, and the location and foundation condition of boils. Expedient methods can be improvised in other ways, to include using sections of corrugated metal piping. Special care must be taken with the design of these structures to make sure there is a reliable means for adjusting the water level, so the water column doesn't completely stop the flow of water through the boil.

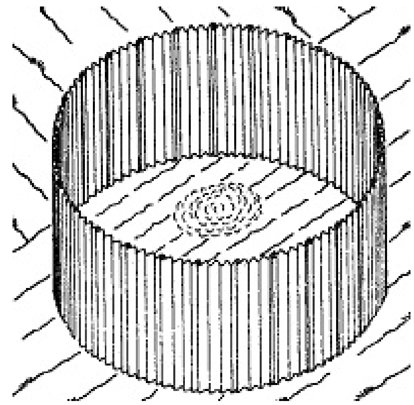


Figure D.9 *A ring of steel-sheet piling can alternately be used to ring the boil, if conditions permit.*

Alternately, it may sometimes be possible to locate the inlet side of a boil under the water on the riverward bank of the levee. A swirl may be observed in the water at this point, or the location of the entry point may have been identified after a previous high water event. Sometimes, because of the current, the swirling vortex appears on the water's surface slightly downstream of the actual opening. If the opening is located, it may be possible to block the seepage flow at its entry point, since blocking the entry point may take much less time than constructing a sandbag ring levee. If the entry point is located, it can be blocked by anchoring a sheet of plastic over the area, using rope and sandbags. It may sometimes be possible to plug a flooded animal burrow by placing a mixture of manure and straw or dry hay into the water at the burrow entrance. If the entry point is blocked, both the blockage and the location of boil need to be closely monitored for any changes.

3.3 Sloughs

If seepage causes saturation and sloughing of the landward slope, the slope should ideally be flattened to 1V (vertical) on 4H (horizontal) or flatter. Material for flattening should be at least as pervious as the embankment material. If any sloughs develop in the levee, all soft areas should be thoroughly drained by excavating shallow ditches in the side slopes, as shown in Plate 4. Contact your Corps district office before undertaking this method.

3.4 Floating Soil Conditions

When seepage exits landward of the levee toe at a pressure that creates a sensation like the soil is fluid, the levee and foundation become susceptible to sliding and/or sloughing which can lead to an embankment failure. A fluid soil condition is an indicator that soil particles or the soil mass is floating, and the soil's ability to support a load such as a vehicle or heavy equipment and/or the levee embankment itself has been reduced. When this condition is observed, the safety, health and welfare of those individuals who are responding to the flood fight and/or those who live within the protected area must come first. Consideration must be given to evacuating the area. If the sod layer appears to pop loose or lift up, evacuate the area immediately. In a past flood, this condition was observed and successfully solved with the placement of clean, free-draining sand fill, classified as SP medium to fine sand, with less than 5 percent fines passing the number 200 sieve. The sand was brought in from another location (away from the levee), and a bulldozer was used to push the sand over the area, creating a blanket some 3 feet in thickness and some 20 feet in width. The thickness and width necessary may vary depending on the observed conditions.

3.5 Other Seepage Related Considerations

Any basement or similar depression near the levee should be closely watched for heaving of floors, caving of walls, and boil activity. It may become necessary to support basement walls or weight down basement floors by intentionally flooding the basement with clean water, to prevent walls from caving in, piping, or excessive seepage.

4. Erosion

4.1 Wave Wash

During high water, continuing wave action against a levee slope can erode wide terraces along the length of the levee. This causes scour or beaching along the riverward slope of the levee and reduces the cross sectional area, which can potentially lead to a failure. This type of damage doesn't typically arise during short (hour-long) storms, especially if the slope has good sod cover. However, during longer periods of high water, especially during windy or icy conditions, the damage can develop very rapidly. The section leader should study the levee beforehand to assess the potential for wave wash. All potential trouble areas should be located well in advance, and section leaders should assemble a reserve supply of materials (filled sandbags, lumber, stakes, plastic sheeting, rock, etc) close to locations most likely to experience such damage. During periods of high wind and high water, when waves attack a levee, ample labor should be assembled and experienced personnel should patrol the areas to identify the beginnings of scour, washouts, or breaching. Because wave wash damage can spread rapidly, it is important that damaged areas are treated as soon as they are identified. There are a number of accepted methods of protecting a levee against wave wash.

a. Sandbags

In emergency situations, the preferred treatment method is to place sandbags in to the cut as shown in Plate 5. The filled sacks should be laid in sections of sufficient length to give protection well above the anticipated rise.

b. Plastic Sheeting and Sandbags

Experience has shown that a combination of plastic sheeting and sandbags is one of the most expedient, effective and economical methods of combating slope attack in a flood situation. Other materials such as snow fence, cotton, or burlap have successfully been used in place of the plastic in the past. Poly and sandbags can be used in a variety of combinations, and time becomes the factor that may determine which combination to use. Ideally, poly and sandbag protection should be placed in the dry. However, many cases of unexpected slope attack will occur during high water, and a method for placement in the wet is covered below. See Plates 6 and 7 for recommended methods of laying poly and sandbags. Plate 8 shows a minimal configuration for emergency use. Since each flood fight project is generally unique (river, personnel available, materials, etc.), specific details of placement and materials handling will not be covered, though some guidelines are provided below. Field personnel must be aware of resources available when using poly and sandbags.

i. Dry Placement

Anchoring the poly along the riverward toe is important for a successful job. It may be done in three different ways: 1) after completion of the levee, a trench excavated along the toe, poly placed in the trench, and the trench backfilled; 2) poly placed flat-out away from the toe, and earth pushed over the flap; 3) poly placed flat-out from the toe and one or more rows of sandbags placed over the flap. The poly should then be unrolled up the slope and over the top enough to allow for anchoring with sandbags. Poly should be placed from downstream to upstream along the slopes and overlapped at least two feet. The poly is now ready for the "hold-down" sandbags.

It is mandatory that poly placed on levee slopes be held down along the slopes as well. An effective method of anchoring poly is a grid system of sandbags, unless extremely high velocities, heavy debris or a large amount of ice is anticipated. Then, a solid blanket of bags over the poly should be used. A grid system can be constructed faster and requires fewer bags and much less labor than a total covering. Various grid systems include vertical rows of lapped bags, two-by-four lumber held down by attached bags, and rows of bags held by a continuous rope tied to each bag. Poly has been held down by a system using two bags tied with rope and the rope saddled over the levee crown with a bag on each slope.

ii. Placement in the Wet

In many situations during high water, poly and sandbags placed in the wet must provide the emergency protection. Wet placement may also be required to replace or maintain damaged poly or poly displaced by current action. Plate 7 shows a typical section of levee covered in the wet. Sandbag anchors are formed at the bottom edge and ends of the poly by bunching the poly around a fistful of sand or rock, and tying the sandbags to this fist-sized ball. Counterweights consisting of two or more sandbags connected by a length of 1/4-inch rope are used to hold the center portion of the poly down. The number of counterweights will depend on the uniformity of the levee slope and current velocity. Placement of the poly consists of first casting out the poly sheet with the bottom weights and then adding counterweights to slowly sink the poly sheet into place. The poly, in most cases, will continue to move down slope until the bottom edge reaches the toe of the slope. Sufficient counterweights should be added to insure that no air voids exist between the poly and the levee face and to keep the poly from flapping or being carried away in the current. For this reason, it is important to have enough counterweights prepared prior to the placement of the sheet.

iii. Overuse of Plastic Sheeting

In past floods, there has been a tendency to overuse and in some cases misuse poly on slopes. For example, on well-compacted clay embankments, in areas of relatively low velocities, use of poly would be excessive. Plastic should never be used on the landward slopes, as it holds through-seepage against the levee slope. A critical analysis of a situation should be made before poly and sandbags are used, with a view toward less waste and more efficient use of these materials and available manpower. However, if a situation is doubtful, poly should be used rather than risk a failure. Critical areas should have priority.

c. Moveable Panels

Wave wash may also be effectively checked by the use of movable panels constructed of lumber. These panels are anchored in place on the levee slope with stakes and are weighted down with sandbags or stone as shown on Plate 9. A portable bulkhead constructed with lumber and staked into placed is another alternate type of wave wash protection.

d. Miscellaneous Measures

Several other methods of slope protection have been used. Straw bales pegged into the slope were successful against wave action, as was straw spread on the slope and overlain with snow fence.

4.2 Scours

Scouring occurs when the current velocity against the levee is adequate to remove levee embankment materials. Once scouring begins to occur, the protective sod cover is damaged or destroyed and additional scour may develop very quickly. Careful observation should be made along the entire length of the riverside of the levee during high water periods, and especially in locations where the current flow is two feet per second or more. Scouring will most likely develop at road crossing ramps and at locations where pipes, sewers, and other structures penetrate the levee. It may also develop in ditches, excavations or building basements near the levee, around riverside stability berms, or in other locations where there is an obstruction to the smooth flow of water along the levee face. If any scour is observed, soundings should be taken if possible to determine the extent of damage and the amount of treatment required.

a. Deflection Weirs

Deflection weirs (also known as bendway weirs), extending 10 feet or more into the channel have been effective in deflecting current away from the levees. These emergency structures can be constructed using lumber, stakes, brush, sandbags, and stone, and are tied in place as shown on Plates 10 and 11. Snow fence, plain riprap, compacted earth or any other substantial materials available may also be used; even old car bodies have been used in the past. Preferably, the weirs should be placed in the dry at locations where severe scour may be anticipated, because construction during high water will be very difficult. A series of weirs may be needed to protect the area, or a longer weir may be constructed in the water parallel to the levee. Care should be given in the placement of weirs, because haphazard placement may be shift the current towards other banks and lead to even worse scouring. Hydraulic technical assistance should be sought if questions arise in the use of emergency weirs.

b. Plastic Sheeting

Plastic sheeting may be useful in protecting the embankment from scouring, as described under the previous section on wave wash.

c. Other Protection

If scour begins to take place after water is up on the levee, a protective berm should be constructed over the entire scour area using stone, slag, or other durable material with sufficient size and weight withstand the erosive velocity of the current. Construction of this berm will generally require equipment capable of operating from the levee crown. Riprap has been used to provide slope protection where erosive forces were too large to be effectively controlled by other means. Objections to using riprap when flood fighting include the cost and the large quantities that are typically necessary to protect a given area. It's usually very difficult to control the placement of the riprap, particularly during times of high water, but careful use of an excavator has been effective even in difficult conditions.

Figure D.10 *Placement of Riprap. Careful use of an excavator may allow for more accurate placement than is shown above.*

4.3 Ice and Floating Debris

Sometimes ice conditions are such that protection provided by the methods outlined above will not be totally effective. The primary method for protecting a levee slope from debris or ice attack is to construct a floating boom parallel to the levee embankment. Logs, driftwood, or any available timber are cabled together end to end and moored to the ground in such a way that they float out in the current about 15 feet from the water's edge. Depending on the size of the logs, the boom will deflect floating objects. Since a detailed discussion of ice jams lies beyond the scope of this manual, please refer to the references in Appendix I for additional information.

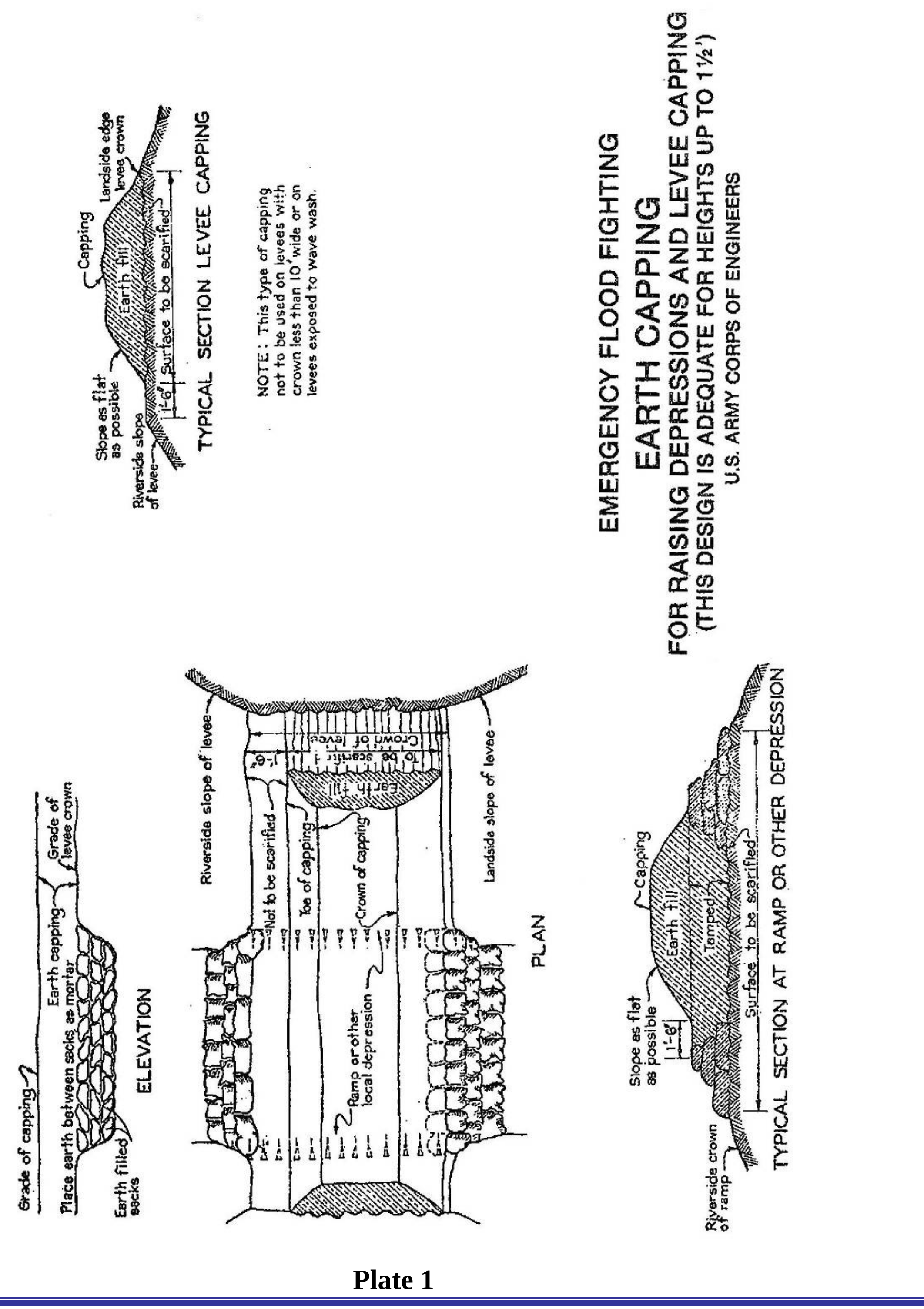

EMERGENCY FLOOD FIGHTING
EARTH CAPPING
FOR RAISING DEPRESSIONS AND LEVEE CAPPING
(THIS DESIGN IS ADEQUATE FOR HEIGHTS UP TO 1½')
U.S. ARMY CORPS OF ENGINEERS
Slope as flat as possible
Riverside slope of levee
Capping
Landside edge levee crown
Earth fill
1'-6"
Surface to be scarified
TYPICAL SECTION LEVEE CAPPING
NOTE: This type of capping not to be used on levees with crown less than 10' wide or on levees exposed to wave wash.
Grade of capping
Place earth between sacks as mortar
Earth filled sacks
Earth capping
Grade of levee crown
ELEVATION
Riverside slope of levee
Not to be scarified
Toe of capping
Crown of capping
Ramp or other local depression
Earth fill
To be scarified
Crown of levee
1'-6"
Landside slope of levee
PLAN
Riverside crown of ramp
Slope as flat as possible
1'-6"
Capping
Earth fill
Tamped
Surface to be scarified
TYPICAL SECTION AT RAMP OR OTHER DEPRESSION

Plate 1

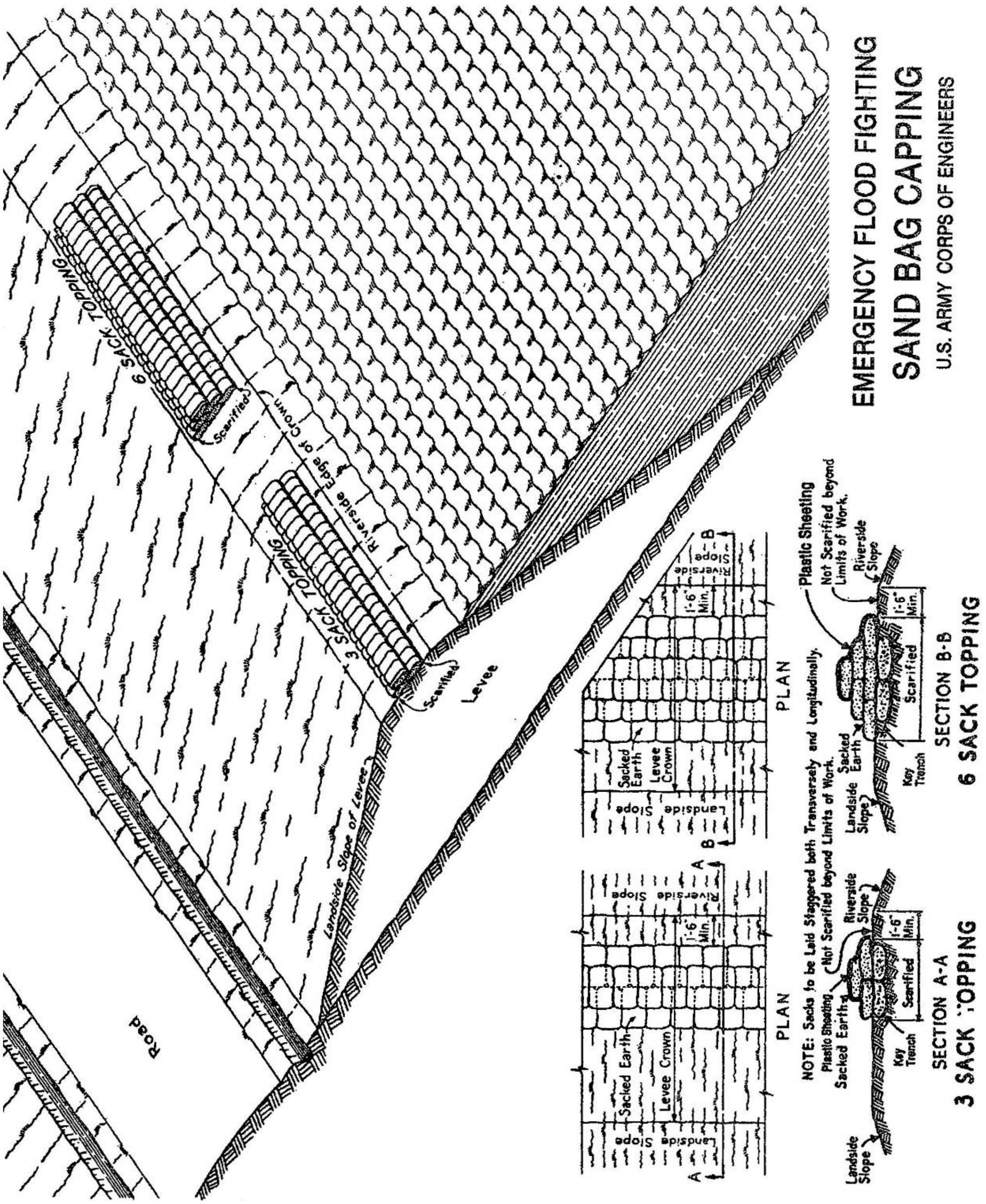
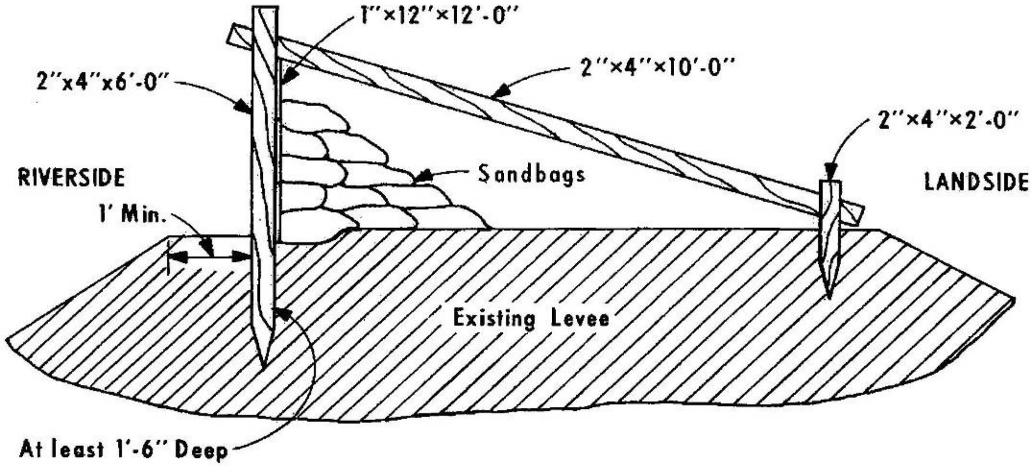
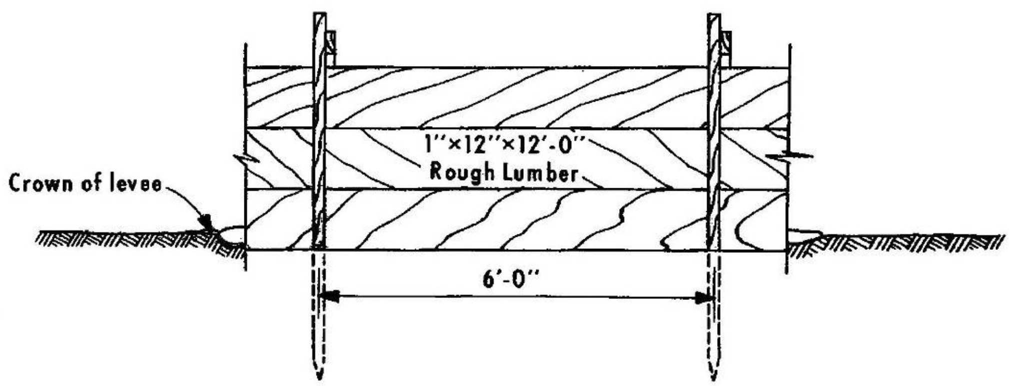

EMERGENCY FLOOD FIGHTING
SAND BAG CAPPING
U.S. ARMY CORPS OF ENGINEERS
6 SACK TOPPING
3 SACK TOPPING
Scarified
Riverside Edge of Crown
Levee
Landside Slope of Levee
Road
PLAN
Sacked Earth
Levee Crown
Landside Slope
Riverside Slope
1'-6" Min.
NOTE: Sacks to be Laid Staggered both Transversely and Longitudinally.
Plastic Sheeting
Not Scarified beyond Limits of Work.
Key Trench
SECTION A-A
3 SACK TOPPING
SECTION B-B
6 SACK TOPPING

Plate 2



SECTION



FRONT ELEVATION

BILL OF MATERIAL FOR 100 FT.
LUMBER
25 pieces 1"×12"×12'-0"
17 pieces 2"×4"×10'-0"
17 pieces 2"×4"×6'-0"
17 pieces 2"×4"×2'-0"
NAILS
2 lbs 8d Common
2 lbs 16d Common
SANDBAGS
1100 Filled Bags

CONSTRUCTION METHODS
FOR
HIGH WATER
LUMBER AND SACK TOPPING
U. S. ARMY CORPS OF ENGINEERS

Plate 3

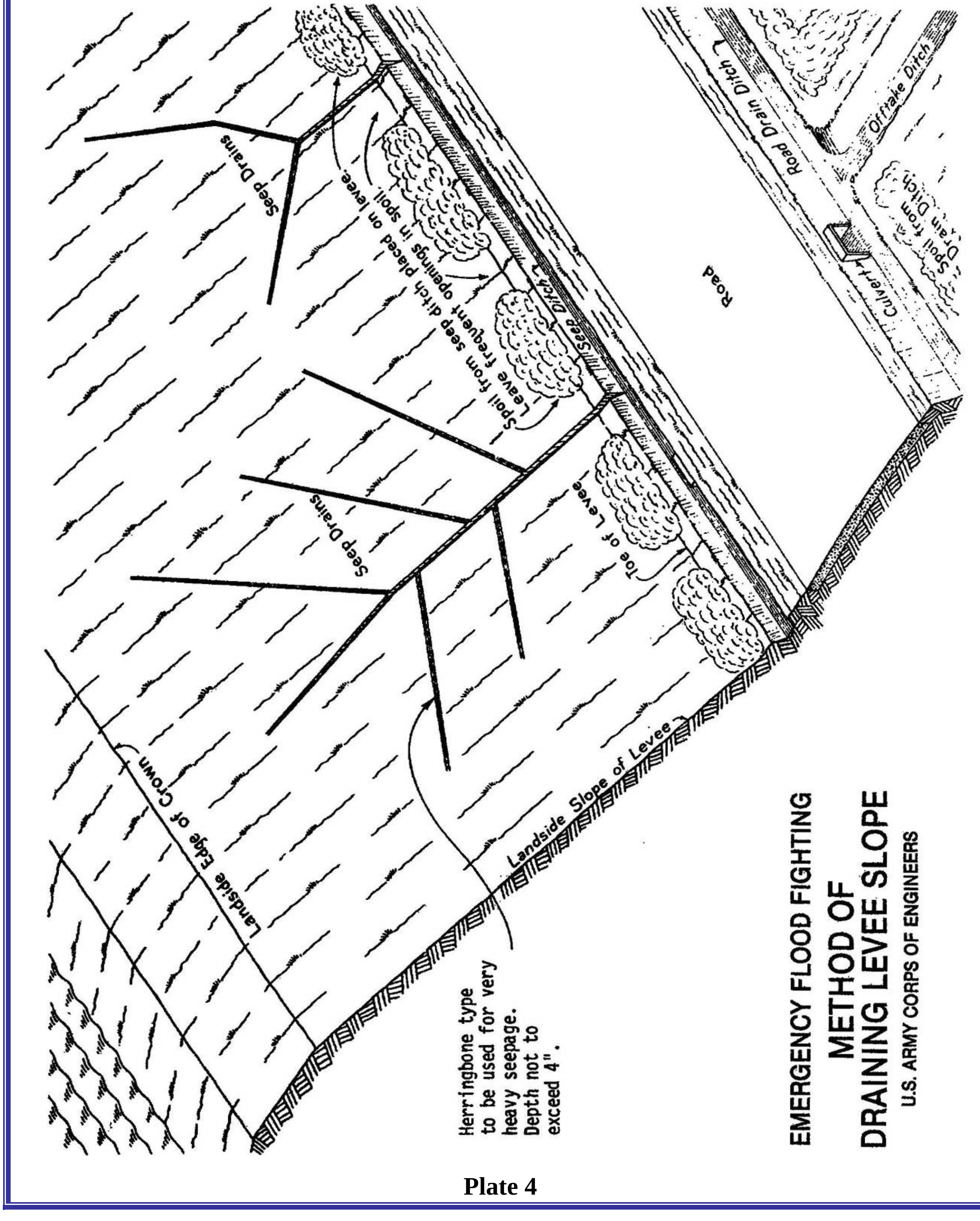

Seep Drains
Leave frequent openings in spoil
Spoil from seep ditch placed on levee
Seep Ditch
Road
Road Drain Ditch
Offtake Ditch
Culvert
Spoil from Drain Ditch
Toe of Levee
Seep Drains
Landside Edge of Crown
Landside Slope of Levee
Herringbone type to be used for very heavy seepage. Depth not to exceed 4".
EMERGENCY FLOOD FIGHTING
METHOD OF
DRAINING LEVEE SLOPE
U.S. ARMY CORPS OF ENGINEERS

Plate 4

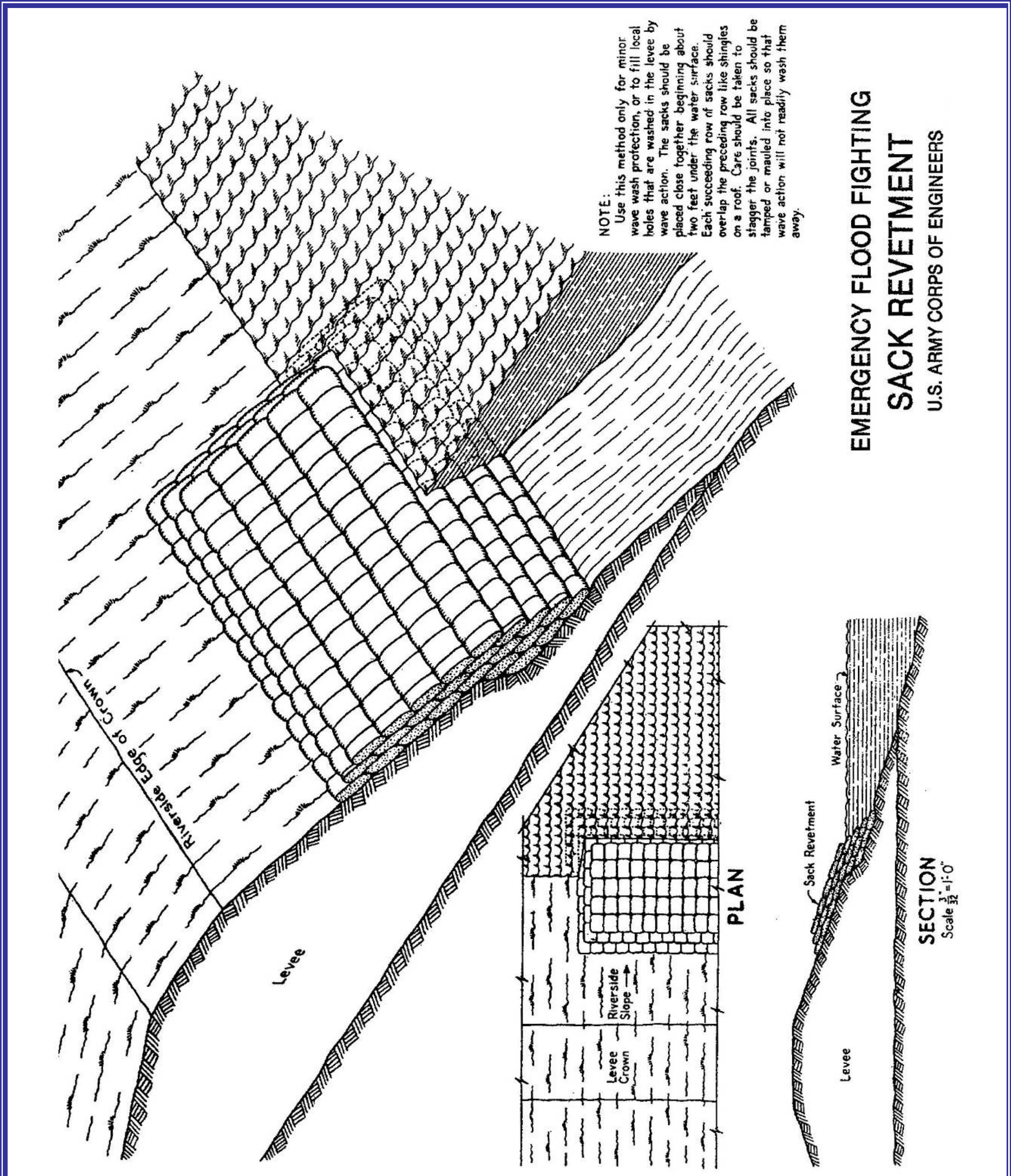

NOTE:
Use this method only for minor wave wash protection, or to fill local holes that are washed in the levee by wave action. The sacks should be placed close together beginning about two feet under the water surface. Each succeeding row of sacks should overlap the preceding row like shingles on a roof. Care should be taken to stagger the joints. All sacks should be tamped or mauled into place so that wave action will not readily wash them away.
EMERGENCY FLOOD FIGHTING
SACK REVETMENT
U.S. ARMY CORPS OF ENGINEERS
Riverside Edge of Crown
Levee
Levee Crown
Riverside Slope
PLAN
Levee
Sack Revetment
Water Surface
SECTION
Scale 3/32"=1'-0"

Plate 5

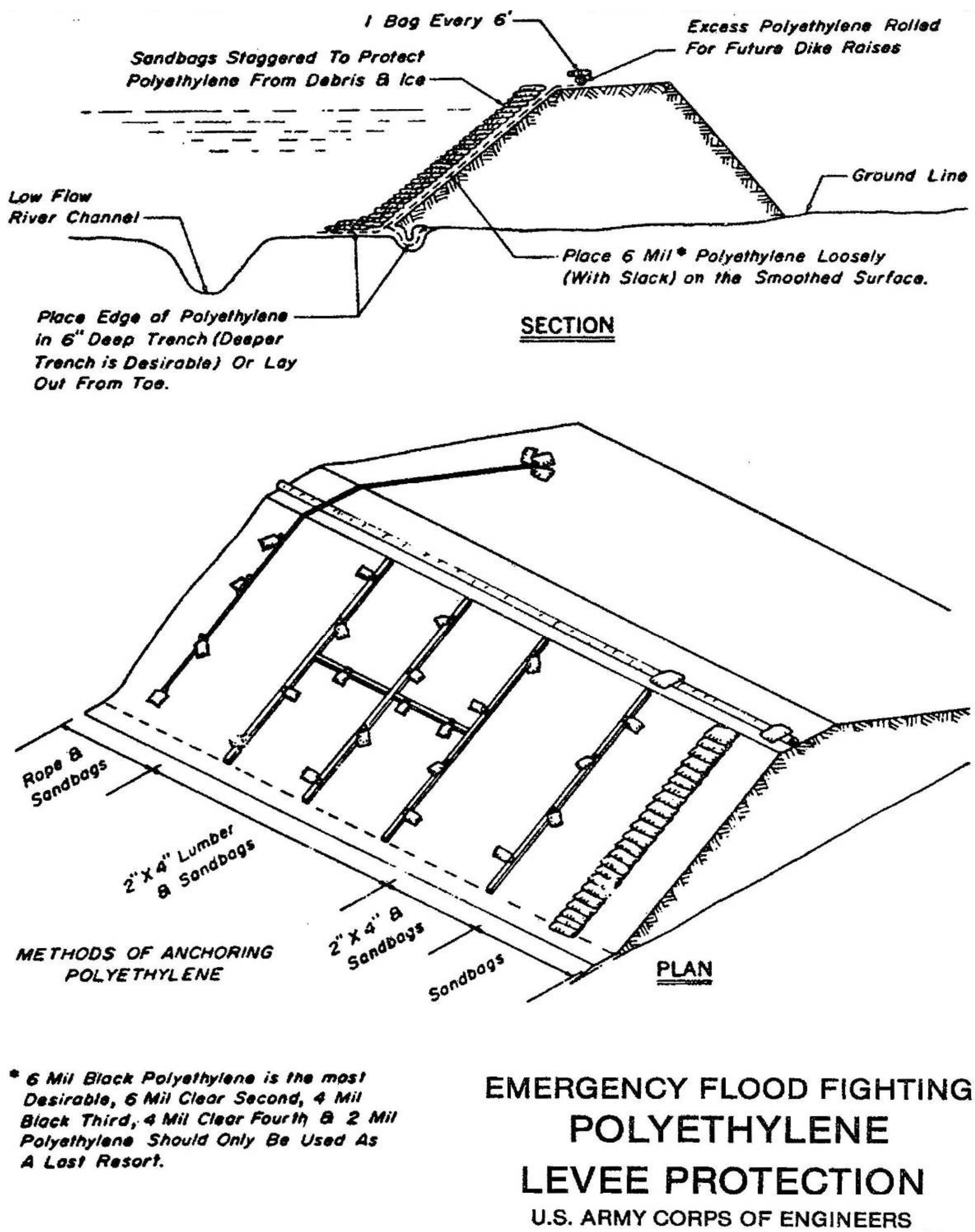
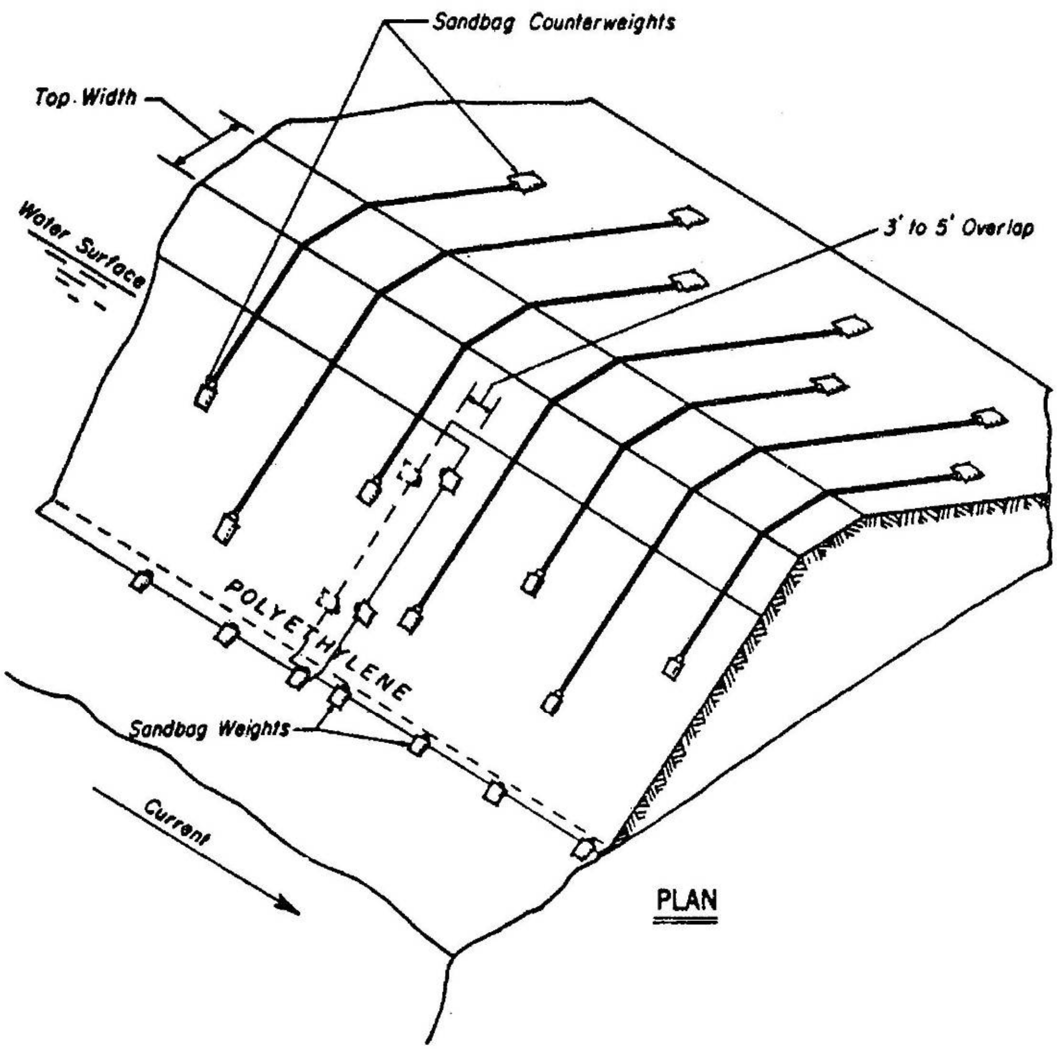
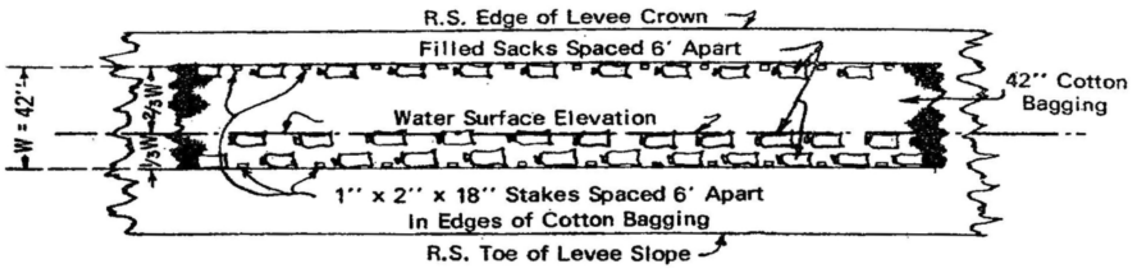

1 Bag Every 6'
Excess Polyethylene Rolled For Future Dike Raises
Sandbags Staggered To Protect Polyethylene From Debris & Ice
Ground Line
Low Flow River Channel
Place 6 Mil* Polyethylene Loosely (With Slack) on the Smoothed Surface.
Place Edge of Polyethylene in 6" Deep Trench (Deeper Trench is Desirable) Or Lay Out From Toe.
SECTION
Rope & Sandbags
2" X 4" Lumber & Sandbags
2" X 4" & Sandbags
Sandbags
METHODS OF ANCHORING POLYETHYLENE
PLAN
* 6 Mil Black Polyethylene is the most Desirable, 6 Mil Clear Second, 4 Mil Black Third, 4 Mil Clear Fourth & 2 Mil Polyethylene Should Only Be Used As A Last Resort.
EMERGENCY FLOOD FIGHTING
POLYETHYLENE
LEVEE PROTECTION
U.S. ARMY CORPS OF ENGINEERS

Plate 6

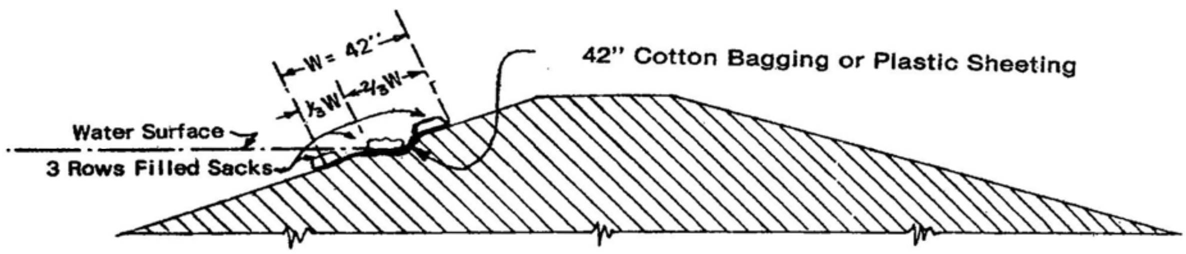


EMERGENCY FLOOD FIGHTING
PLACEMENT OF
POLYETHYLENE
SHEETING IN THE WET
U.S. ARMY CORPS OF ENGINEERS

Plate 7



PLAN



CROSS SECTION

BILL OF MATERIAL
TO CONSTRUCT 180 FT.

1 Roll Jute Cotton Bagging 42'' x 180'
90 Filled Sacks
60 Stakes 1'' x 2'' x 18'' = 15 Bd. Ft.

INSTRUCTIONS

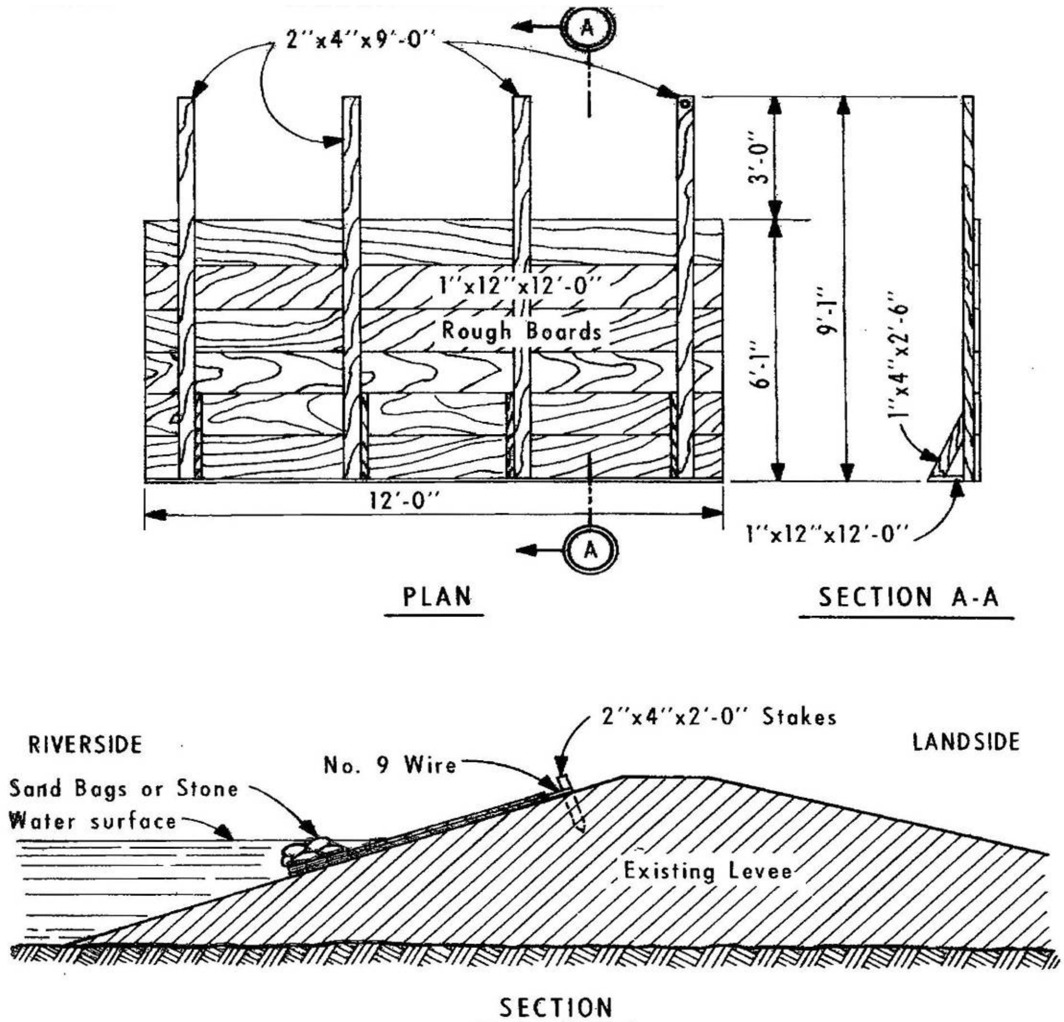
Lay 42'' cotton bagging (Jute) longitudinally along riverside slope of levee with approximate 2/3 width above water surface.

Weight bagging along edges and at water surface with filled sacks spaced approximately 6' apart. Drive stakes alternately between sacks along both edges of bagging.

If additional width is required, lace two or more widths of bagging together and lay as desired.

EMERGENCY FLOOD FIGHTING
TYPE OF WAVEWASH PROTECTION
U.S. ARMY CORPS OF ENGINEERS

Plate 8



BILL OF MATERIAL FOR 100 FT.
LUMBER
55 Pieces 1"x12"x12'-0" 32 Pieces 1"x4"x2'-6" 32 Pieces 2"x4"x9'-0" 32 Pieces 2"x4"x2'-0"
WIRE
100 Ft. No. 9
NAILS
6lbs. 8d Common

CONSTRUCTION METHODS
FOR
HIGH WATER
WAVE WASH PROTECTION MOVABLE
U. S. ARMY CORPS OF ENGINEERS

Plate 9

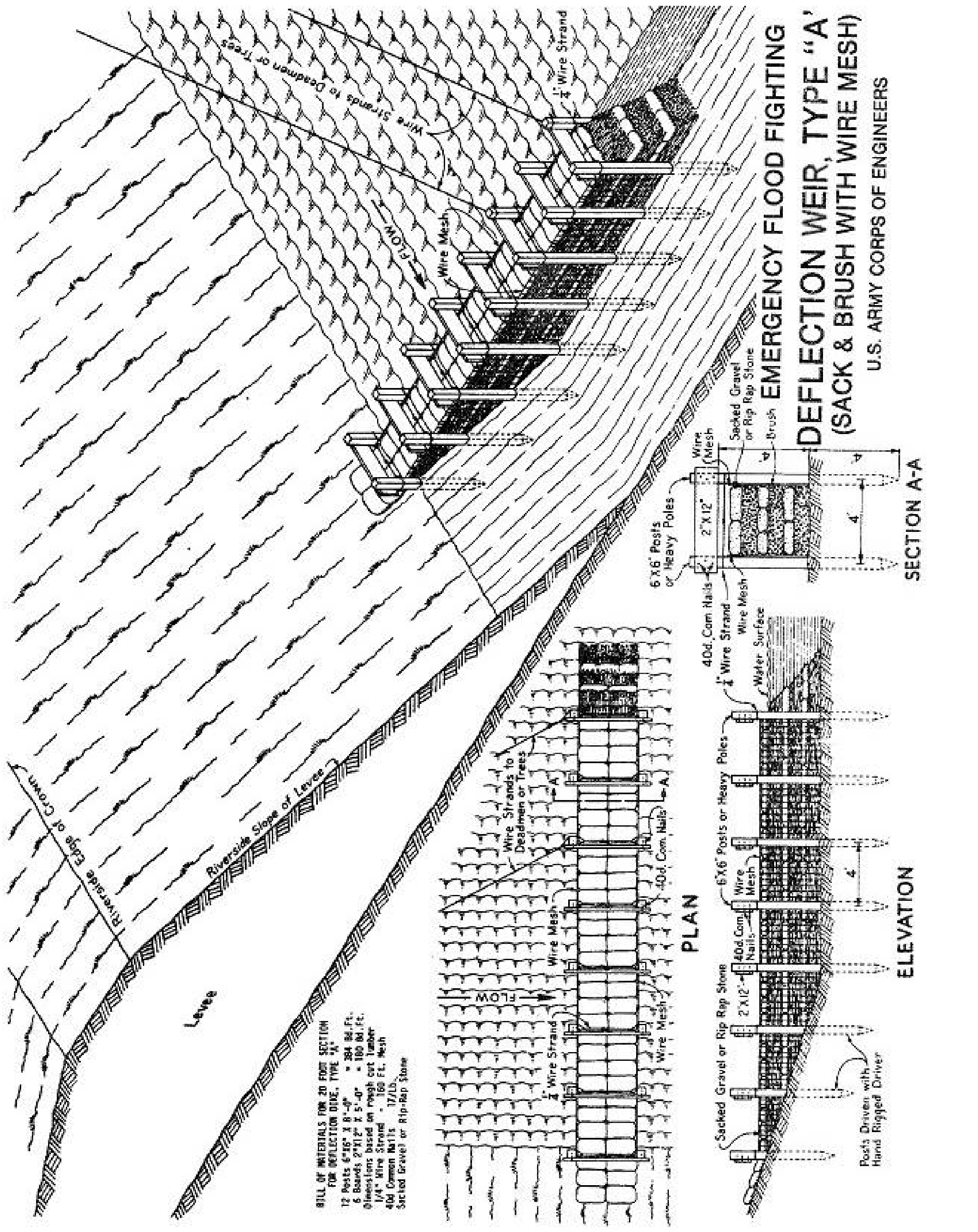

EMERGENCY FLOOD FIGHTING
DEFLECTION WEIR, TYPE "A"
(SACK & BRUSH WITH WIRE MESH)
U.S. ARMY CORPS OF ENGINEERS
PLAN
ELEVATION
SECTION A-A
Riverside Edge of Crown
Riverside Slope of Levee
Levee
FLOW
Wire Mesh
Wire Strands to Deadmen or Trees
$\frac{1}{4}$" Wire Strand
6"X6" Posts or Heavy Poles
40d Com. Nails
2"X12"
Sacked Gravel or Rip Rap Stone
Brush
Water Surface
Posts Driven with Hand Rigged Driver

Plate 10

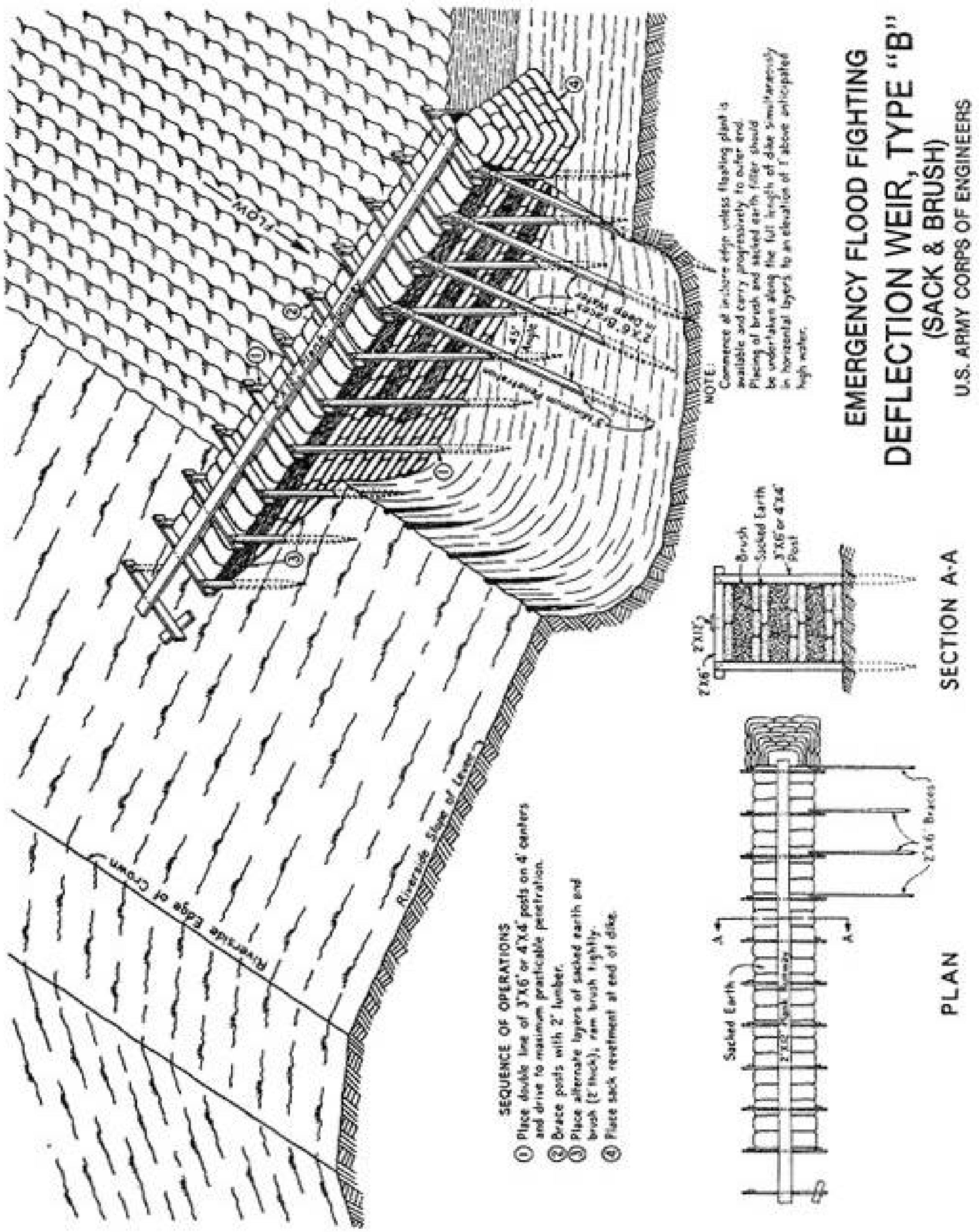

EMERGENCY FLOOD FIGHTING
DEFLECTION WEIR, TYPE "B"
(SACK & BRUSH)
U.S. ARMY CORPS OF ENGINEERS
NOTE:
Commence at inshore edge unless floating plant is available and carry progressively to outer end. Placing of brush and sacked earth filler should be undertaken along the full length of dike simultaneously in horizontal layers to an elevation of 1' above anticipated high water.
SEQUENCE OF OPERATIONS
① Place double line of 3"X6" or 4"X4" posts on 4' centers and drive to maximum practicable penetration.
② Brace posts with 2" lumber.
③ Place alternate layers of sacked earth and brush (2' thick); ram brush tightly.
④ Place sack revetment at end of dike.
FLOW
Riverside Edge of Crown
Riverside Slope of Levee
Brush
Sacked Earth
3"X6" or 4"X4" Post
SECTION A-A
Sacked Earth
2"X6" Braces
PLAN

Plate 11

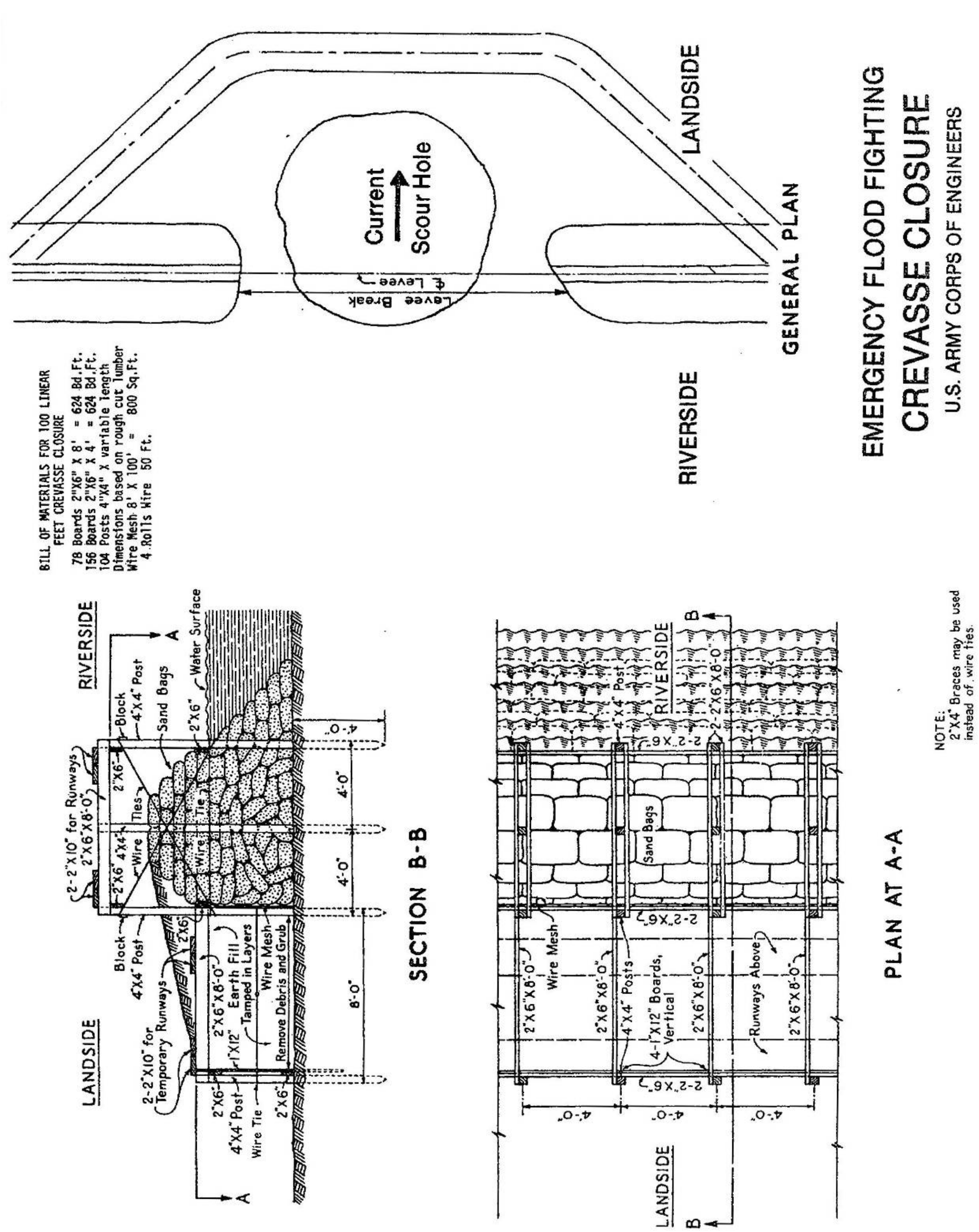
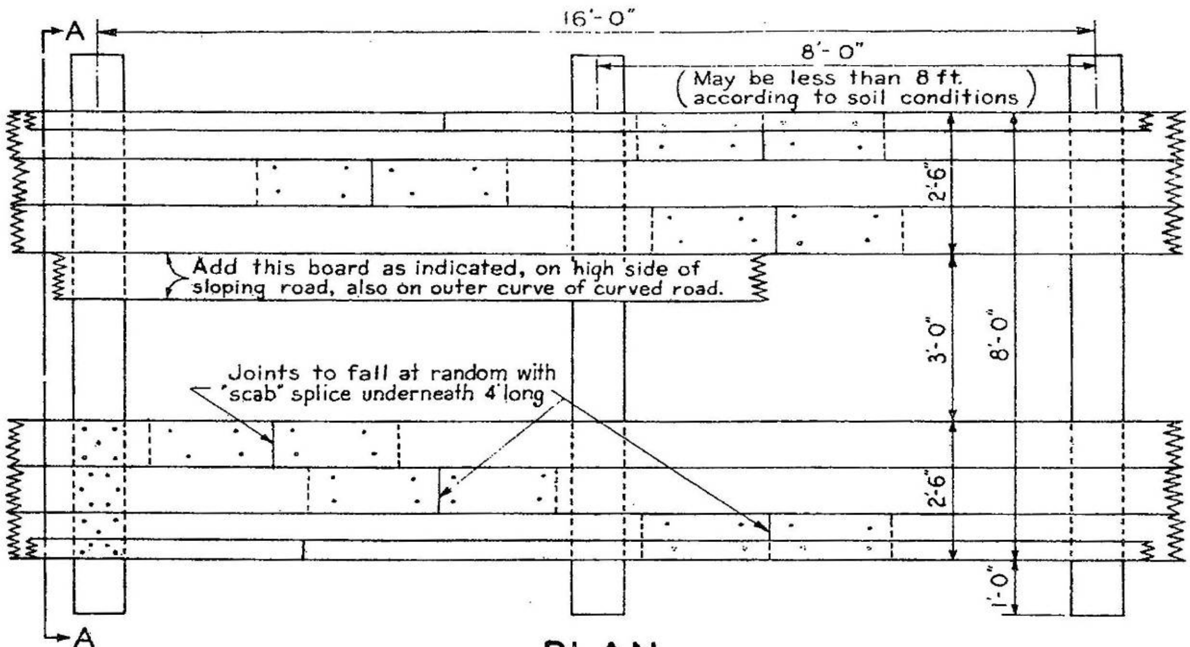
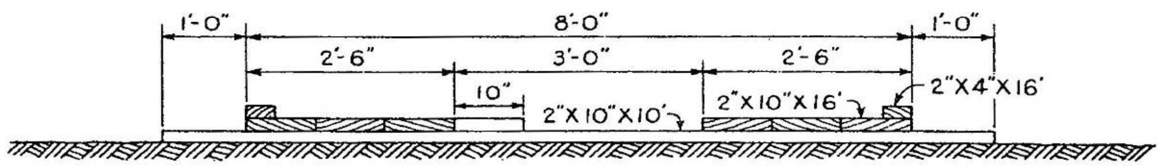

EMERGENCY FLOOD FIGHTING
CREVASSE CLOSURE
U.S. ARMY CORPS OF ENGINEERS
GENERAL PLAN
LANDSIDE
RIVERSIDE
Current
Scour Hole
Levee Break
℄ Levee
BILL OF MATERIALS FOR 100 LINEAR FEET CREVASSE CLOSURE
78 Boards 2"X6" X 8' = 624 Bd.Ft.
156 Boards 2"X6" X 4' = 624 Bd.Ft.
104 Posts 4"X4" X variable length
Dimensions based on rough cut lumber
Wire Mesh 8' X 100' = 800 Sq.Ft.
4 Rolls Wire 50 Ft.
SECTION B-B
2-2"X10" for Runways
2"X6"X8'-0"
Block
4"X4" Post
Sand Bags
Water Surface
2-2"X10" for Temporary Runways
Wire Tie
Wire Ties
Earth Fill Tamped in Layers
Wire Mesh
Remove Debris and Grub
1"X12"
4'-0"
8'-0"
PLAN AT A-A
NOTE: 2"X4" Braces may be used instead of wire ties.
Runways Above
4-1"X12" Boards, Vertical
4"X4" Posts
2-2"X6"
Sand Bags

Plate 12



PLAN

Scale $\frac{3}{8}$" = 1'- 0"



SECTION A-A

Scale $\frac{1}{2}$" = 1'- 0"

BILL OF MATERIALS FOR 100 LINEAR FEET OF ROADWAY

Cross Members	13 Pcs. 2"X10"X10' =	217 Bd. Ft.
Road Bed	38 Pcs. 2"X10"X16'* =	1014 Bd. Ft.
Guard Rail	13 Pcs. 2"X4"X16'* =	139 Bd. Ft.
	Total	1370 Bd. Ft.

18 Lbs. 30d. Common Nails
10 Lbs. 60d. Common Nails

Kind of Lumber: Hardwood, Rough.

Actual quantities. No allowance made for waste.

NOTE:
Where foundation is very soft, 12 ft. flooring should be used with cross members at 6 ft. centers. In this case add approximately $33\frac{1}{3}$% or $\frac{1}{3}$ to Bill of Materials at left, for 100 ft. of roadway.

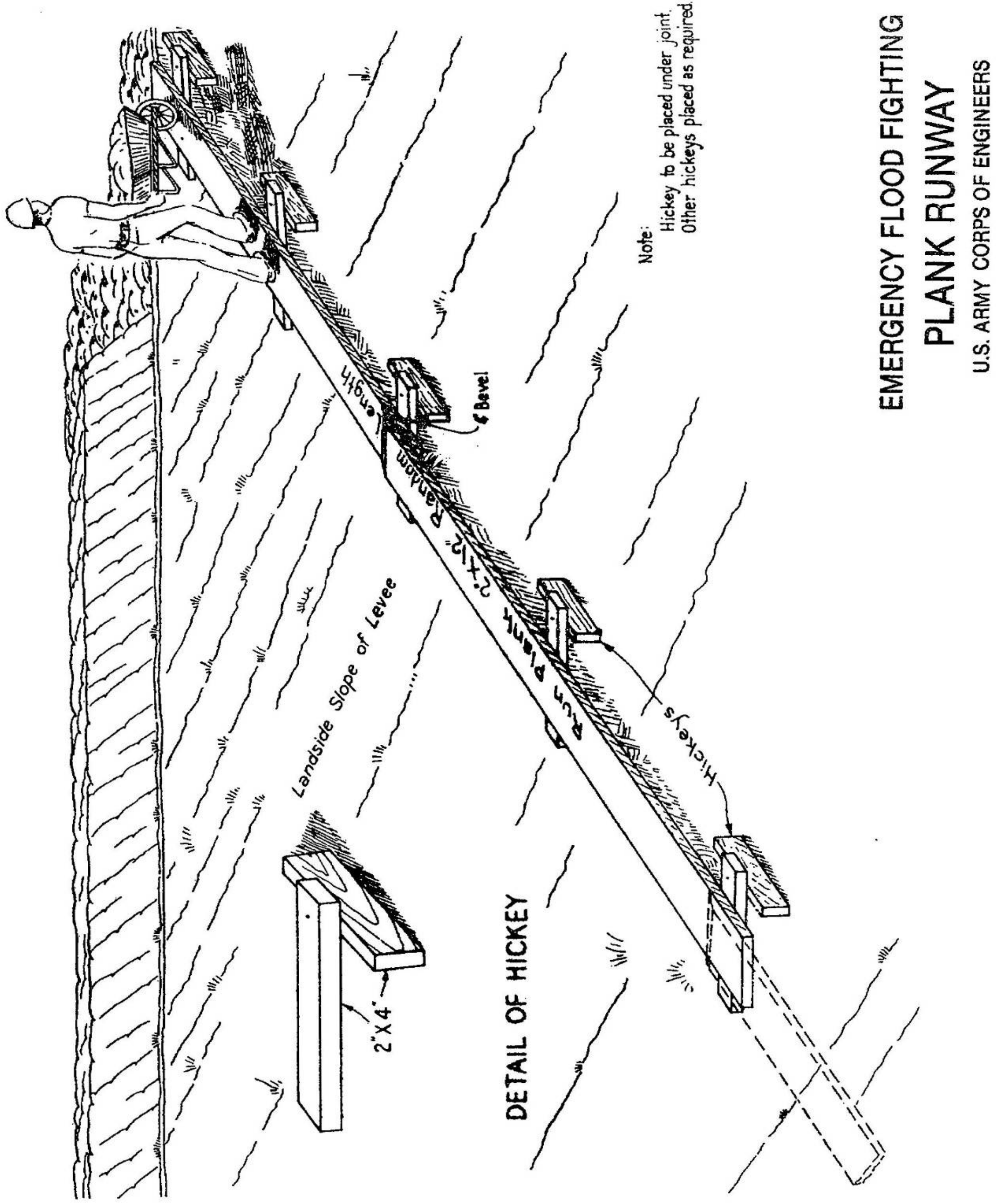
* Random not less than 12'

EMERGENCY FLOOD FIGHTING

PLANK ROAD

U.S. ARMY CORPS OF ENGINEERS

Plate 13



EMERGENCY FLOOD FIGHTING
PLANK RUNWAY
U.S. ARMY CORPS OF ENGINEERS
Note:
Hickey to be placed under joint.
Other hickeys placed as required.
Random Length 2"x12" Run Plank
Bevel
Hickeys
Landside Slope of Levee
DETAIL OF HICKEY
2"X4"

Plate 14

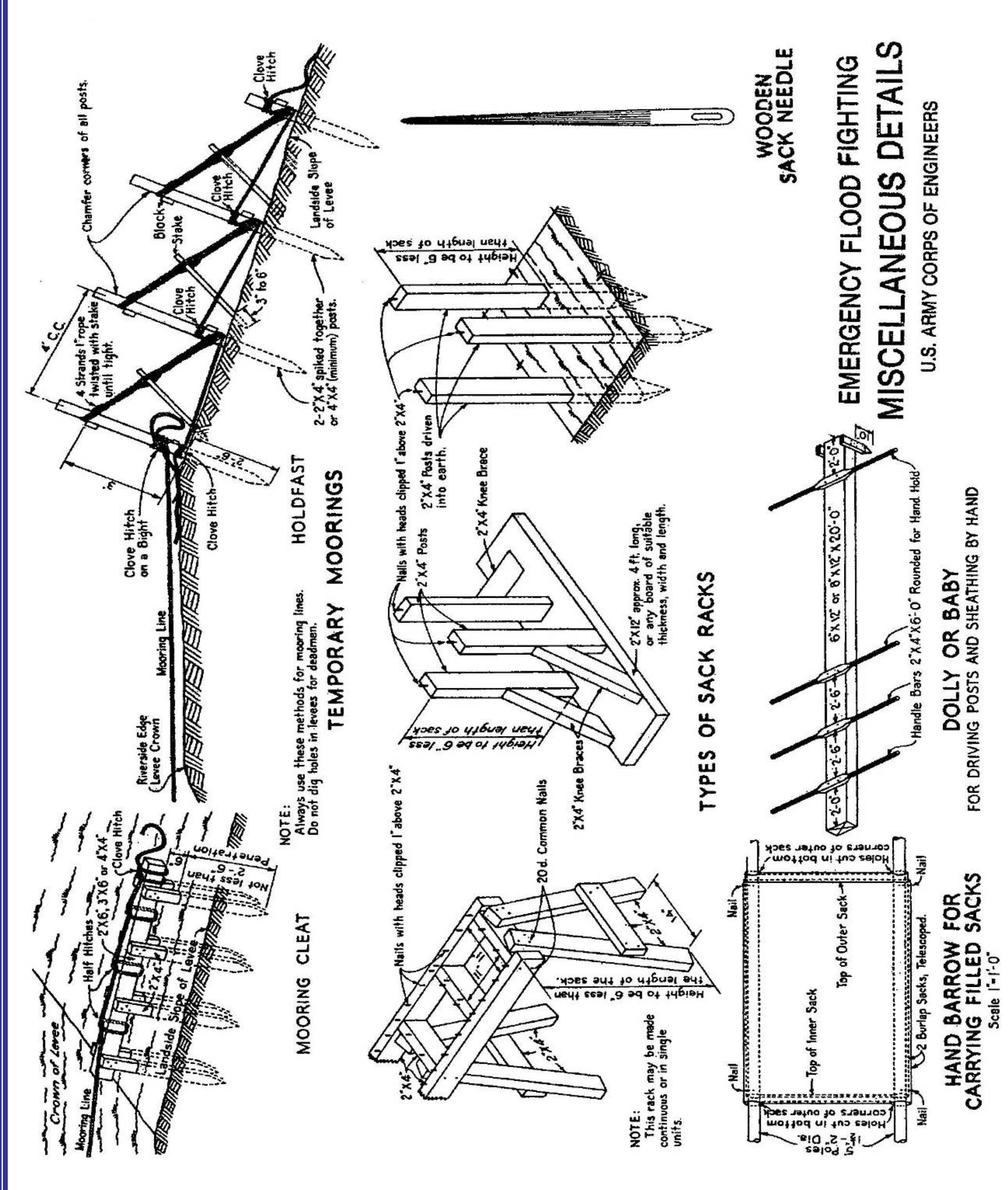

EMERGENCY FLOOD FIGHTING
MISCELLANEOUS DETAILS
U.S. ARMY CORPS OF ENGINEERS
TEMPORARY MOORINGS
HOLDFAST
MOORING CLEAT
NOTE:
Always use these methods for mooring lines.
Do not dig holes in levees for deadmen.
TYPES OF SACK RACKS
NOTE:
This rack may be made continuous or in single units.
WOODEN SACK NEEDLE
DOLLY OR BABY
FOR DRIVING POSTS AND SHEATHING BY HAND
HAND BARROW FOR CARRYING FILLED SACKS
Scale 1"=1'-0"
Chamfer corners of all posts.
4 Strands 1" rope twisted with stake until tight.
2-2"X4" spiked together or 4"X4" (minimum) posts.
Landside Slope of Levee
Clove Hitch
Clove Hitch on a Bight
Mooring Line
Riverside Edge Levee Crown
Crown of Levee
Half Hitches
2"X6", 3"X6" or 4"X4"
Landside Slope of Levee
Nails with heads clipped 1" above 2"X4"
20d. Common Nails
2"X4" Knee Braces
2"X4" Posts
2"X4" Posts driven into earth.
2"X4" Knee Brace
2"X12" approx. 4 ft. long, or any board of suitable thickness, width and length.
Height to be 6" less than length of sack
Handle Bars 2"X4"X6'-0" Rounded for Hand Hold
6"X12" or 8"X12"X20'-0"
Top of Inner Sack
Top of Outer Sack
2 Burlap Sacks, Telescoped.
Holes cut in bottom corners of outer sack
Nail

Plate 15